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THE TEHUANTEPEC SHIP RAILWAY.

THE name of James B. Eads will be recorded in the history of the United States with lasting characters, as one of her greatest engineers. In this capacity no comparison can be instituted between him and De Lesseps, who can lay no claim to engineering skill, but only to a great diplomatic and administrative genius. In these latter qualities, however, we think there is little to choose between him and Mr. Eads, who, if he successfully achieves his present bold and all-absorbing project, will have overcome as many difficulties, physical and moral, as ever De Lesseps encountered in digging the Suez Canal. It is not our intention to present anything like a complete biography of Mr. Eads, but a few of the salient incidents of his life will suitably preface a notice of the great work with which he hopes to crown his long and useful career.

Like so many of America's great men, Mr. Eads has been the engineer of his own fortune. He was born on May 23, 1820, in the village of Lawrenceburg, Indiana,

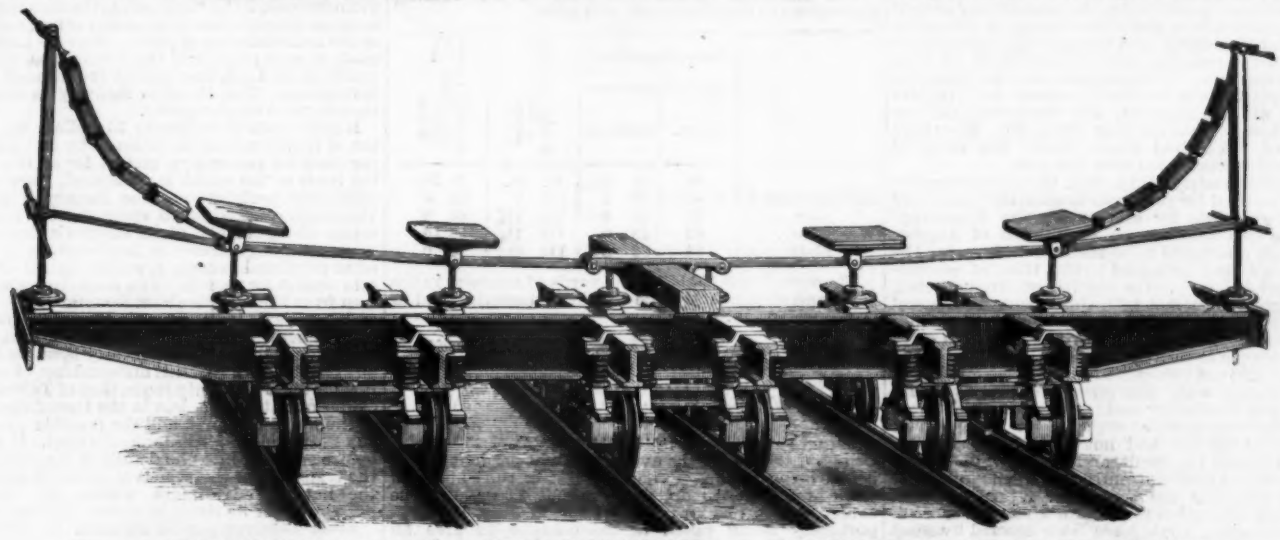


FIG. 2.—THE INTEROCEANIC SHIP RAILWAY.- A SECTION OF THE GREAT CAR.

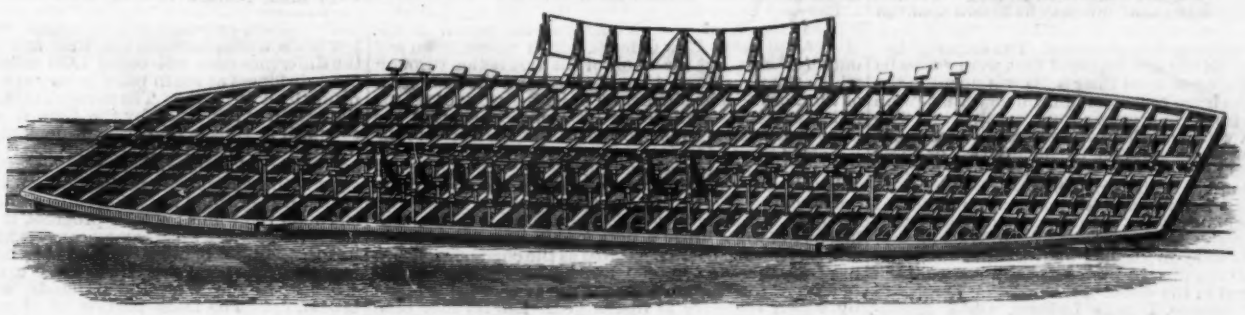


FIG. 3.—GENERAL VIEW OF THE GREAT CAR.

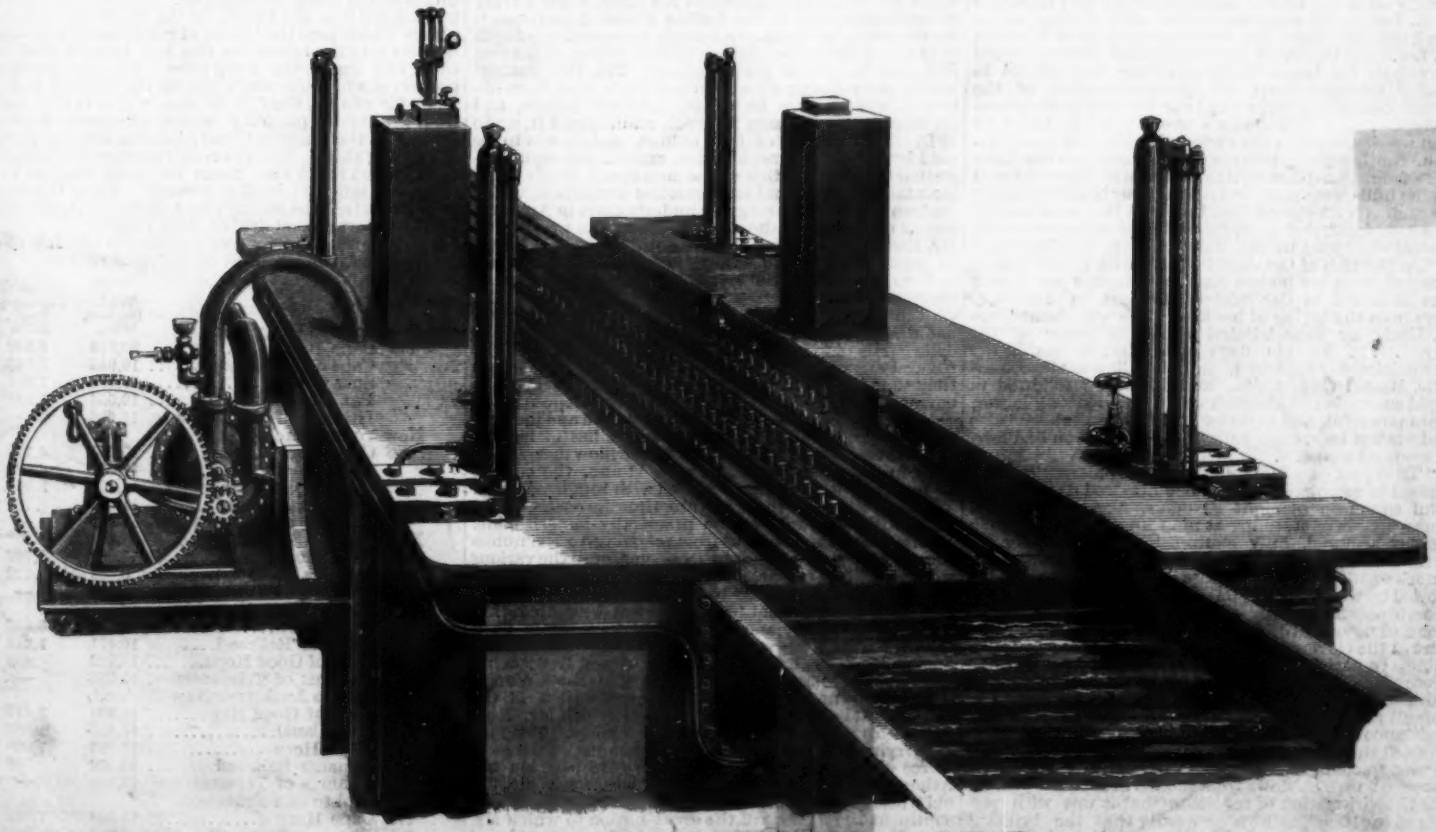


FIG. 1.—THE INTEROCEANIC SHIP RAILWAY.

and was removed with his family to St. Louis, thirteen years later. At that time circumstances compelled him to seek such employment as his age and neglected education fitted him for. Having obtained it, he devoted his scanty leisure to study, and even at this early time his interest appears to have been centered on the phenomena presented by the mighty stream from which he was destined afterward to gain name and fortune. When eighteen years of age the never ceasing attraction exercised on him by the Mississippi led him to take the situation of a steamboat clerk, and the years he spent in traveling up and down the river gave him full opportunities for becoming intimately acquainted with all its varieties of floods and currents, and their action on the navigable channels by the destruction of banks and deposition of sediment. During this time he had perfected several inventions having special reference to hydraulic engineering—diving-bells, submarine boats, sand pumps, machinery for raising sunken vessels, removing snags, etc. As a natural result, Mr. Eads quitted his employment on the steamboat, and soon established himself as an engineer at St. Louis, where he soon became well known and appreciated.

When the Civil War blazed out, Mr. Eads had made far more than a local reputation, and was on the road to fortune. His ability and energy were known and valued at Washington as well as at St. Louis, for his name had become prominent as the promoter of several projects connected with the improvement of the navigation of the Mississippi, and he was then recognized as an authority upon that subject, as well as an able mechanical engineer. The war gave him an opportunity for displaying the wonderful energy and powers of resource which distinguish his character, and we cannot refrain from quoting from Mr. Boynton's "History of the United States Navy" the story of Mr. Eads' chief connection with the war:

"During the month of July, 1861, the Quartermaster-General advertised for proposals to construct a number of ironclad gunboats for service on the Mississippi River. The bids were opened on the 5th of August, and Mr. Eads was found to be the best bidder for the whole number, both in regard to the time of completion and price. . . . On the 7th of August, 1861, Mr. Eads signed a contract with Quartermaster-General Meigs to construct these seven vessels ready for their crews and armaments in sixty-five days. At this early period the people in the border States, especially in the slave States, had not yet learned to accommodate themselves to a state of war. The pursuits of peace were interrupted; but the energy and enterprise which were to provide the vast material required for an energetic prosecution of the war had not then been aroused. None could foresee the result, and a spirit of doubt and distrust pervaded financial and commercial circles. It was at this time that the contractor returned to St. Louis with an obligation to perform what, under ordinary circumstances, would have been deemed by most men an impossibility. Rolling mills, machine shops, foundries, forges, and saw-mills were all idle. The demands of peace had ceased for months before, and the working men were enlisting, or seeking in States more quiet their accustomed employment. The engines that were to drive this our first ironclad fleet were yet to be built. The timber to form their hulls was uncut in the forests, and the huge rollers and machinery that were to form their iron armor were not yet constructed. The rapidity with which all these various parts were to be supplied forbade depending alone on any two or three establishments in the country, no matter how great were their resources. The signatures were scarcely dry on this important contract before persons in different parts of the country were employed upon the work through telegraphic orders issued from Washington. Special agents were dispatched in every direction, and saw-mills were simultaneously occupied in cutting the timber required in the construction of the vessels, in Kentucky, Tennessee, Illinois, Indiana, Ohio, Minnesota, and Missouri; and railroads, steamboats, and barges were engaged for its immediate transportation. Nearly all of the largest machine shops and foundries in St. Louis, and many small ones, were at once set at work day and night, and the telegraph lines between St. Louis and Pittsburg and Cincinnati were occupied frequently for hours in transmitting instructions to similar establishments for the construction of the twenty-one steam engines and the five-and-thirty steam boilers. . . . Within two weeks not less than 4,000 men were engaged in the various details of its construction. Neither the sanctity of the Sabbath nor the darkness of night was permitted to interrupt it. The workmen on the hulls were promised a handsome bonus in money for each one who stood steadfastly at the work until it was completed, and many thousands of dollars were thus gratuitously paid by Mr. Eads when it was finished.

"On the 12th of October, 1861, the first United States ironclad, with her boilers and her engines on board, was launched in Carondelet, Missouri, in forty-five days from the laying of her keel. She was named the St. Louis, by Rear-Admiral Foote, in honor of the city. . . . In ten days after the De Kalb, the Carondelet was launched, and the Cincinnati, Louisville, Mound City, Cairo, and Pittsburg followed in rapid succession. An eighth vessel (the Benton), larger, more powerful, and superior in every respect, was also undertaken before the hulls of the first seven had fairly assumed shape. . . .

"Thus just one individual put in construction and pushed to completion within one hundred days a powerful squadron of eight steamers, aggregating 5,000 tons, capable of steaming at nine knots per hour, each heavily armored, fully equipped, and all ready for their armament of 107 large guns. The fact that such a work was done is nobler praise than any that can be bestowed by words. It is to be regretted, however, that the promptness and energy of the man who thus created an ironclad navy on the Mississippi were not met on the part of the Government with an equal degree of faithfulness in performing its part of the contract. On one pretext or another, the stipulated payments for the work were delayed by the War Department, until the default assumed such magnitude that nothing but the assistance rendered by patriotic and confiding friends enabled the contractor, after exhausting his own ample means, to complete the fleet. Besides the honorable reputation which flows from success in such a work, he has the satisfaction of reflecting that it was with vessels at the time his own property that the brilliant capture of Fort Henry was accomplished, and the conquest of Donelson and Island Number Ten achieved. The ever memorable midnight passage of Island Number Ten by the Pittsburg and the Carondelet, which compelled the surrender of that powerful stronghold, was performed by vessels furnished four or five months previous by the same contractor, and at the time unpaid for."

After the close of the Civil War, Mr. Eads addressed himself to the solution of a great engineering problem which the development of railways had rendered absolutely necessary—the bridging of the Mississippi. A company for the execution of this work was initiated in 1864; the bill was approved February 15, 1865, and work was commenced August 20, 1867. In this, as in his later and more important work—the Mississippi jetties—Mr. Eads met with much personal opposition, which, however, mattered little to a man of his temperament and ability. Not only was the design of Mr. Eads for this monumental work then unprecedented in its dimensions, but the difficulties encountered in its execution were also unprecedented. It was decided to cross the river in three arched spans of about 500 ft. each. As a matter of fact, the actual spans were:

	Feet.
West span	502·075
Center span	520·394
East span	502·342

The following figures give some of the leading dimensions of the abutments and piers:

	Dimensions at Base.		Height from Base to Top of Masonry.	Depth of Foundation below Extreme Low Water.
	Length.	Thickness.		
	ft.	ft. in.	ft. in.	ft. in.
East abutment.	83	70 6	192 9	94 0
" pier	82	60 0	197 1½	85 0
West pier	82	48 0	172 1¼	56 10
" abutment.	94	62 8½	112 8½	18 0

There are in all 102,897 cubic yards of masonry in the piers and abutments. The weight of material used in the superstructure was:

	Lb.
Steel	4,780,000
Wrought iron	6,313,000
Timber	1,612,000
Railway tracks, etc.	430,000
Total	13,135,000

Or about 6,500 tons, the average weight per foot run of bridge being 4·3 tons. The total cost of the completed work was 6,536,729 dollars, or about 1,300,000*l*. The bridge was opened for public traffic in July, 1874, opportunity being taken of the occasion to give an ovation to Mr. Eads, the magnitude of which was almost unparalleled even in the United States.

The next great work to which Mr. Eads devoted himself was the creation of an outlet at the mouth of the Mississippi below New Orleans, which would open not only that city, but the whole of the vast region through which the river flows, to navigation and the commerce of the world. The Mississippi in its network of 100,000 miles passes through nearly 1,000 million acres of the most fertile lands of the United States, and receives the waters of most of the other great rivers, the Missouri, the Ohio, the Arkansas, and the Red River. The enormous amount of solid matter brought down to the sea and discharged through the delta of the Mississippi is equal annually to 770,805,000,000 cubic yards, sufficient to form a prism a mile square and 268 ft. high; and this burden being deposited as the current slackens, has from time immemorial formed bars at the mouths of each of the various passes of the ever-growing delta by which the river is discharged. Efforts had been made since 1726 to remove these obstacles to navigation, but nothing really practical was attempted till 1874, when Mr. Eads, having formed his plans, made a truly characteristic offer to the United States Government. He proposed to open and maintain a channel at a depth of 28 ft. for the sum of ten millions of dollars, at his own risk and the risk of his associates. The Government was to pay nothing till a depth of 20 ft. had been obtained, when he was to receive 1,000,000 dollars, and afterward the same sum for each additional 2 ft. up to 28 ft. The balance of five million dollars was to be paid by the Government in ten annual and equal installments, on condition of the maximum depth being maintained. Personal and senseless opposition, which too frequently disgraces great undertakings in America, was at once busy in the effort to defeat the proposal of Mr. Eads, and was so far successful that he was forced to confine his work to the South Pass of the delta, and to execute it on a smaller scale, under more rigorous conditions.

In 1875, Mr. Eads commenced his work in the great flat desert of mud, reeds, and water that forms the delta. His plan was to construct, on each side of the natural channel, jetties at such a distance apart that they should, by contracting the channel, quicken the current, and thus not only prevent the deposition of sediment, but should scour out the bottom and increase the depth. Each jetty was over two miles in length, and was constructed of tiers of woven willow mattresses, sunk in position, and loaded with stones, the surface above water level being protected with rough masonry. The interstices in the structure thus formed quickly filled with silt, and became practically imperishable. Want of space prevents us from referring to the numerous difficulties which were overcome, or to the various works that had to be carried out, auxiliary to the main scheme. It must suffice to say that in July, 1879, a channel 26 ft. deep and 165 ft. wide was completed, that the depth of this channel continued to increase until the prescribed limit was reached, and that the work of James B. Eads has raised New Orleans from being the eleventh to the second export city in the Union.

We turn now to a detailed consideration of the gigantic and original undertaking on which Mr. Eads is concentrating all his energy and ability. The idea of carrying across the Isthmus of Tehuantepec the commerce which flows backward and forward between the Atlantic and the Pacific and Indian Oceans, was already old when the Pilgrim Fathers planted on the American continent the nucleus of the great nation to which Mr. Eads belongs. Cortez himself sought for a natural way along the rivers which flow in either direction to the sea, and finding none he purchased large tracts of land as an inheritance to his posterity, confident that in time the needs of the world and the advance of science would carry a highway over this very spot. His descendants still hold these lands, which lie in the exact track settled by recent surveys as the route for the proposed ship railway, and thus they will reap the fruits of a piece of statesmanlike farsightedness which stands in remarkable contrast with the timidity and supineness of a generation which, having seen more marvels of science and engineering than the whole human race which preceded them, can scarcely be got to believe that it is possible to raise a laden ship out of the water without breaking her back.

During the three centuries which have elapsed since Cortez in imagination saw his grandchildren levying toll upon the Oriental traffic which has enriched one nation after another, passing successively through the hands of the Arabians, the Phœnicians, the Venetians, the Portuguese, and the Dutch, until it finally settled in England, the idea of cutting or crossing the narrow isthmus which connects North and South America has never been long forgotten, and for the last quarter of a century there have always been some ardent minds at work upon it. There are three points on the isthmus which naturally suggest themselves as the sites of any attempt at crossing, viz., Panama, Nicaragua, and Tehuantepec, as at these points the distance from ocean to ocean is much less than at any other, and the height of the mountains is not great. Surveys have been often made at each place, and the first named, from the small width of the land, has become the scene of two serious enterprises. The Panama Railway is known to all, though not very favorably.

It costs from 10 dollars to 25 dollars to transport a ton of freight across the isthmus by rail, and 25 dollars per head for passengers, and as far as the great carrying trade of the world is concerned, these charges are absolutely prohibitive. The Panama Canal is being vigorously pushed on in spite of great obstacles, and under the guidance of its energetic designer will no doubt, if enough money be forthcoming, be accomplished in time, and become a success as far as affording a safe transit for vessels. The second crossing, as will be seen from the map, is about 550 miles north of Panama, and has just been conceded to the United States Government, which, it is understood, have guaranteed to cut a canal there. In an early issue we hope to give an extended notice of this undertaking. For the present it is the most northerly route, that of Tehuantepec, that claims our attention, but in the face of the competition of the Panama Canal, and the possible antagonism of the State-aided Nicaragua channel, it will be well, before entering into the details of the method by which the transport of the vessels is to be effected, to notice the natural advantages which Mr. Eads' scheme possesses over its rivals in virtue of its location.

From Tehuantepec to Panama is 1,200 miles, while more than half that distance intervenes between it and Nicaragua. In many voyages the saving effected by crossing the isthmus by the northern route, in place of the southern, amounts to 2,000 miles, while there are few trade tracks between the west and east in which the difference does not equal 1,000 miles. But to express distances at sea in miles is very apt to mislead the reader by half-truths. The savage's idea, which defines the length of a journey by the time it requires to accomplish it, thus taking account not only of its extent, but also of its difficulty, is far better adapted for a comparison for commercial purposes than the usual geographical measures. Seeing how much of the world's commerce is carried in sailing ships, which are dependent upon the winds for their progress, it will be understood that steady breezes may convert knots into cable lengths, while baffling calms lengthen them into leagues. The northeast trade winds extend across the Atlantic to the West India Islands, where they are broken up. The main portion of them is lost, and never reaches the Caribbean Sea, which is known to the mariner as an area of calm to be carefully avoided unless he has steam at command. This windless stretch is extended into the Pacific by the chain of mountain ranges which runs the length of the isthmus, and which deflects into the upper air the few breezes that find their way on to the steep sides. But the northeast portion of the trade winds misses the islands and extends far into the Gulf of Mexico, which is thus saved from the torrid placidity which blockades both entrances to the Panama Canal against a large proportion of existing ships. Thus to cross from ocean to ocean by the Panama route may mean far more than an extra thousand miles, at least at present. When the steamship has driven the sailing vessel off the sea, trade winds will have lost a good deal of their value.

The following table shows the lengths of a few of the principal maritime courses by different routes:

	Total Distance. Miles.	Excess over Tehuantepec Route. Miles.
New York to Hong Kong		
via Cape Horn	20,379	8,777
Cape of Good Hope	16,945	5,343
Suez Canal	13,596	1,994
Panama Railroad	12,953	1,351
Isthmus of Tehuantepec,	11,602	—
New York to Melbourne		
via Cape Horn	15,215	4,150
Suez Canal	15,171	4,106
Cape of Good Hope	15,019	3,954
Panama Railroad	11,826	761
Isthmus of Tehuantepec,	11,065	—
New York to San Francisco		
via Cape Horn	15,687	10,797
Panama Railroad	6,063	1,173
Isthmus of Tehuantepec,	4,890	—
Liverpool to Hong Kong		
via Cape Horn	20,606	5,353
Panama Railroad	16,471	1,218
Cape of Good Hope	15,722	469
Isthmus of Tehuantepec,	15,253	—
Liverpool to Auckland, New Zealand,		
via Cape of Good Hope	16,221	3,412
Suez Canal	16,645	1,836
Cape Horn	13,897	1,088
Panama Railroad	13,312	503
Isthmus of Tehuantepec,	12,809	—
Liverpool to San Francisco		
via Cape Horn	15,803	7,527
Panama Railroad	8,885	609
Isthmus of Tehuantepec,	8,276	—

It is not necessary to give the saving in distance between New Orleans and the leading ports in the Pacific and Indian oceans; a glance at the map shows it more clearly even than figures.

Tehuantepec is thus seen to be on the direct course from China, Japan, Australia, New Zealand, California, and the whole Pacific coast of America to New York and Europe, while it is the natural communication between the two parts of the United States which are severed by the Rocky Mountains. How urgently such a passage is needed is shown by the immense efforts that have been made to complete the various transcontinental railroads, which are quite unsuited for the transport of heavy merchandise of a cheap character. Last year 1,200,000 tons of Californian wheat were carried to Europe round Cape Horn, being unable to bear the freight charges of the direct route to New York. But no part of the States will benefit by the ship railway more than the Mississippi Valley and its tributaries, with its many millions of inhabitants. It has a splendid waterway to carry its productions into the Gulf of Mexico, but when they arrive there they find one-half the world closed against them.

The Isthmus of Tehuantepec lies immediately north of the promontory of Yucatan, and is the narrowest part of the Isthmus of Mexico. A line drawn between the two termini of the proposed railway is almost due north and south. The ground has been often surveyed with the idea of cutting a canal, and notably in 1774 by Don Augustin Cramer, in 1824 by Don Tadeo Ortiz and Don Juan de Orbegoso, in 1842–1843 by Senor Moro, and in 1852 by Mr. J. J. Williams on the part of the Tehuantepec Railway of New Orleans. This latter engineer is associated with the present project, and several of his colleagues have been engaged in previous undertakings in the same neighborhood. The concession granted to Mr. Eads gives a right of way across the country about one-quarter of a mile in width, upon which he may construct a ship railway and a line of telegraph. He also enjoys a free right of way on public lands; exemption from all duties on ships, passengers, and merchandise in transit: free importation of all materials required for the railway; exemption from all taxes and contributions on capital stock and property; a grant of 1,000,000 acres of public lands; and a guarantee of protection by the military and naval forces of the country without expense. The terminus of the railway on the north is on the banks of the Coatzacoalcos River at the town of Minatitlan, about 25 miles from the mouth of the river. This is a broad, deep stream, and requires improvement by artificial means only at one point. At the mouth of the river is a bar formed by deposit, and this it is designed to deepen by jetties similar to those at the mouth of the Mississippi. There is now about 15 ft. of water over the bar. The line ascends by easy gradients of 42 ft. to the mile over the Atlantic plains for about 35 miles. It then enters a gently undulating tableland, from which it passes by a series of broad valleys to the summit level, the Tarifa plains, 726 ft. above the sea. The descent from this point to the Pacific plains has a uniform grade of 1 in 100, and requires three deflecting turntables, for curves of less than 20 miles radius are inadmissible from the form of the carriage, as will be seen later on. From the base of the mountains to the Pacific terminus the line extends over a nearly level country, the station being either at Salina Cruz or on one of the lagoons, as may be found convenient. The climate of the country is quite salubrious, and the surveying parties have been at work there for seventeen months, part of them in the rainy season, without any sickness.

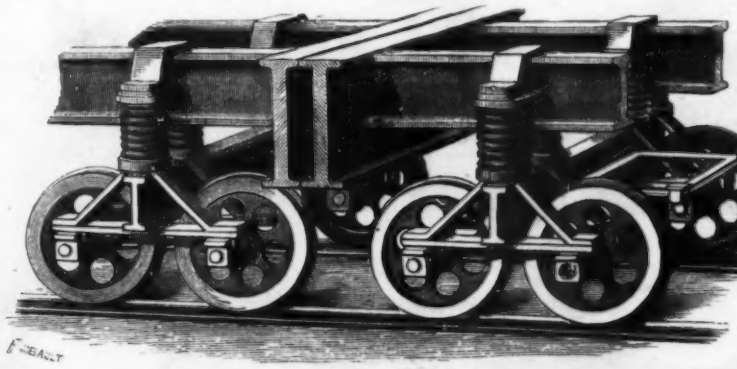
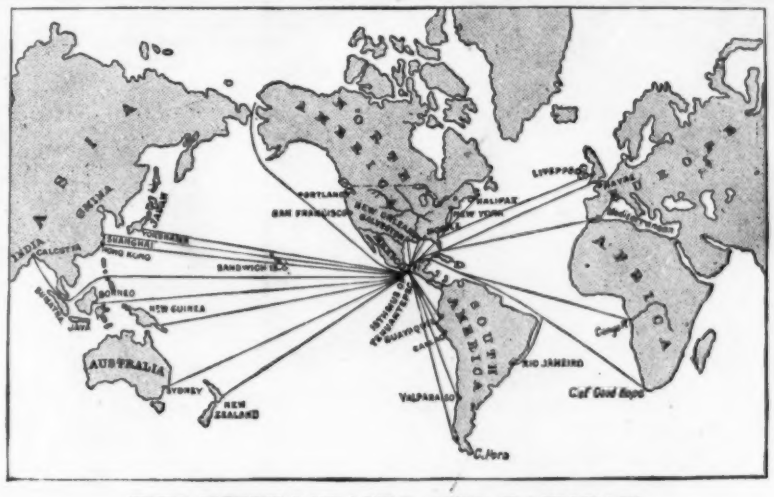


FIG. 4.—GROUP OF INDEPENDENT WHEELS AND AXLES.

Having thus described the position which Mr. Eads has selected for his ship railway, we will now turn to the line itself, and to the means which have been devised for raising vessels out of the sea, placing them on carriages, and returning them at the end of the journey to their natural element. To make the explanation clear, we have prepared engravings of a working model railway, which was constructed for Mr. Eads by Messrs. Holtzapffel & Co., of Long-acre, London.



THE INTEROCEANIC SHIP RAILWAY.

As a project of this kind appeals for support to many who have no knowledge of engineering, this splendid model, a part only of which we illustrate in this issue, was prepared to aid the comprehension of the details. It was seen by many hundreds of people while in London, and he must have been an exceedingly clear-headed man who did not feel that the method of operation came home much more vividly to his mind after he had watched it rehearsed in miniature than when his knowledge was derived only from verbal or written descriptions. The model has since been taken to the States, where it has been shown to all the leading men of the railroad and shipping interests. It is far from being a toy: the model steamer is 7½ ft. long, the car 6 ft. 4 in. long, the deck 7 ft. 6 in. by 2 ft. 6 in., and the basin holds two tons of water. It is a reduction to scale from the full-sized dock, which contains a pontoon 450 ft. long, 75 ft. wide, and 15 ft. deep; but the reduction has not been carried out in the servile spirit of the professional model maker, who delights in reproducing every detail with the exactest fidelity. The broad, general features of the intended apparatus are copied, but not constructive details; and the engines, pumps, and pipes are represented by hand apparatus, by which the various effects can be produced with greater celerity and certainty than could be attained with smaller machines.

To lift a vessel from the river to the railroad she will be moved into a narrow dock, of which one end is open to the stream while the other faces the terminus of the track, which ends on the dock wall. At the bottom of the water there will lie, when the vessel enters, a submerged pontoon of rectangular form, having on its upper face or deck six lines of rails of corresponding gauge to those which form the track on shore.

The pontoon can be sunk or raised by pumping water into or out of it, and when the vessel has been placed in position over it, the pumps are set to work, and the pontoon rises. It comes up gradually, in consequence of two towers which stand partly above the water, and decrease the buoyancy of the whole structure as they are raised. When the carriage approaches the keel of the ship, the pumps are stopped, and an automatic arrangement, which will be explained later, seats the vessel upon the keel blocks in such a way that its weight is uniformly and exactly distributed over the whole length and breadth of the car, all the wheels carrying equal loads. When this has been accomplished, the pumps are set to work again, and the pontoon and ship rise until the rails stand flush with those on the dock wall, when the car can be drawn on to the shore, and be started on its journey to the other terminus, where, by aid of a second pontoon, it can be lowered into the ocean. So much for the general idea. A host of difficulties to be encountered before such a delicate operation can be conducted with safety and rapidity will occur at once to the reader, and we shall now proceed to show, by aid of illustrations, how Mr. Eads proposes to guard the process against accident. See Figs. 1, 7, 8.

The essential condition is that the pontoon shall rise with its upper surface perfectly horizontal, whether the load be exactly in the center or not, and shall maintain its position as the car is moved along it, and while the weight is being transferred from the center to the end, and is finally removed to the shore. In the engraving (Fig. 1) the pontoon is shown in its highest position, and the dock is represented by a wrought iron tank partly decked at either side, and thus hiding a part of the pontoon. The deck is cut away in two places to allow the towers to pass through it. These towers are of such a length that the machinery they bear on their summits never descends below the level of the dock wall. They carry a set of hydraulic pumps, which are connected by pipes with a system of hydraulic presses mounted on an intermediate deck of the pontoon about 6 ft. below the upper surface. The rams of these presses are visible in the figure, and are seen to be arranged in seven longitudinal rows. They are also disposed in rows crosswise, the central rows comprising seven presses, and those nearer the ends five and three presses respectively, while at the extreme ends there is only one longitudinal row, and consequently the cross rows become single presses. The aggregate area of the rams in each cross row, whether it contain one, three, five, or seven presses, is always the same, and as they are all exposed to the same water pressure per square inch, it follows that the lifting action per unit of length of the ship is equal. Of course a vessel does not weigh an equal amount per foot run from end to end, but her girder-like form is well capable of transmitting a part of the load amidships to the bows and the stern. In lifting the vessel, the pressure of the rams is transmitted through columns fitted with keel and bilge blocks, as will be explained when we come to the car. All the presses are connected to the same pipe, which affords communication with the pump in the tower, and thus the pontoon can rise and fall without in any way interfering with the action of the rams. Provision is made also for arranging the presses in groups if desired, and transmitting a different pressure to each group.

The pontoon is made to rise and fall quite vertically by the four sets of hydraulic rams shown at the corners of the docks. Each set consists of two cylinders and two rams, the cylinders being fixed to the dock wall, and the rams to the pontoon. One cylinder is inverted and projects upward, working over a ram standing upon the deck of the pontoon, while the other cylinder hangs downward, and has its ram connected to the pontoon by two side rods. The cylinders at the diagonally opposite corners are connected together in pairs, the inverted cylinder being coupled to the upright cylinder, and *vice versa*. The whole system is filled with water, and a moment's consideration will show that the water forced out of one press must be received in the corresponding one, and that this is only possible when the plungers move at similar rates. Supposing that, as the pontoon stands in the engraving, 100 tons were piled at one end, that end would immediately begin to sink, but in doing so it would force water out of two inverted presses at the opposite ends, and the other extremity of the pontoon would be pressed down at exactly the same speed as the loaded part. Such a case assumes the structure to be floating idly with no reserve of buoyancy, a condition in which it would be manifestly impossible

FIG. 5.—THE INTEROCEANIC SHIP RAILWAY.—THE HYDRAULIC TURNTABLE.

to run a heavily laden car upon it. In actual work it is guided in its rise and fall by large pillars acting as anchor rods, and when it has attained the proper level, these rods prevent any further rise. The pumping is then continued until the pontoon is sufficiently buoyant to receive its full load without sinking at all, and then the only influence of an unequally distributed weight is to create a hydraulic pressure which holds down the opposite end of the structure and keeps the whole horizontal.

The office of the pontoon is to raise the ship, while the presses distribute the weight evenly among themselves, each cross row taking an equal proportion of the whole. Supposing there are fifty rows of presses, and the gross weight of the ship is 5,000 tons, then each row will sustain 100 tons, and a pressure gauge on the pipe system will register the pressure per square inch of area of the rams, and from this the total weight of the ship and cargo may be deduced. The pressure in the presses is not obtained by the hydraulic pump, but by the gradual settling down of the vessel on to the keel and bilge blocks as she is raised out of the water by the pontoon. The hydraulic pump merely elevates the rams until the blocks obtain a gentle hold of the ship, and then it is stopped, and the pump which empties the pontoon is restarted. As the buoyancy of the ship is decreased by more and more of her bulk being raised out of the water, there is a gradually increasing load put on the rams, which are free to adjust themselves, some rising and others falling a trifle, until they come to a state of equilibrium. The presses form a part of the permanent equipment of the pontoon, and therefore, before the vessel and car can be moved, means have to be provided to maintain the balance which has been brought about. To this end there is interposed between the head of each ram and the corresponding block a column having a screw thread cut upon it, as shown in Fig. 2, which is a perspective view of one section or member of the car, near the center of its length. (See also Fig. 7, parts 1 and 4.) Upon this thread there is a nut which can take a firm bearing upon the cross girder. Before the car is sunk with the pontoon, these nuts are screwed up to the tops of the columns or thereabouts, so that the blocks may sink to their lowest positions, and when the car emerges with its load, the nuts all stand clear of the girders. They are then all screwed down by hand until they take a firm bearing and prevent the columns and blocks from moving.

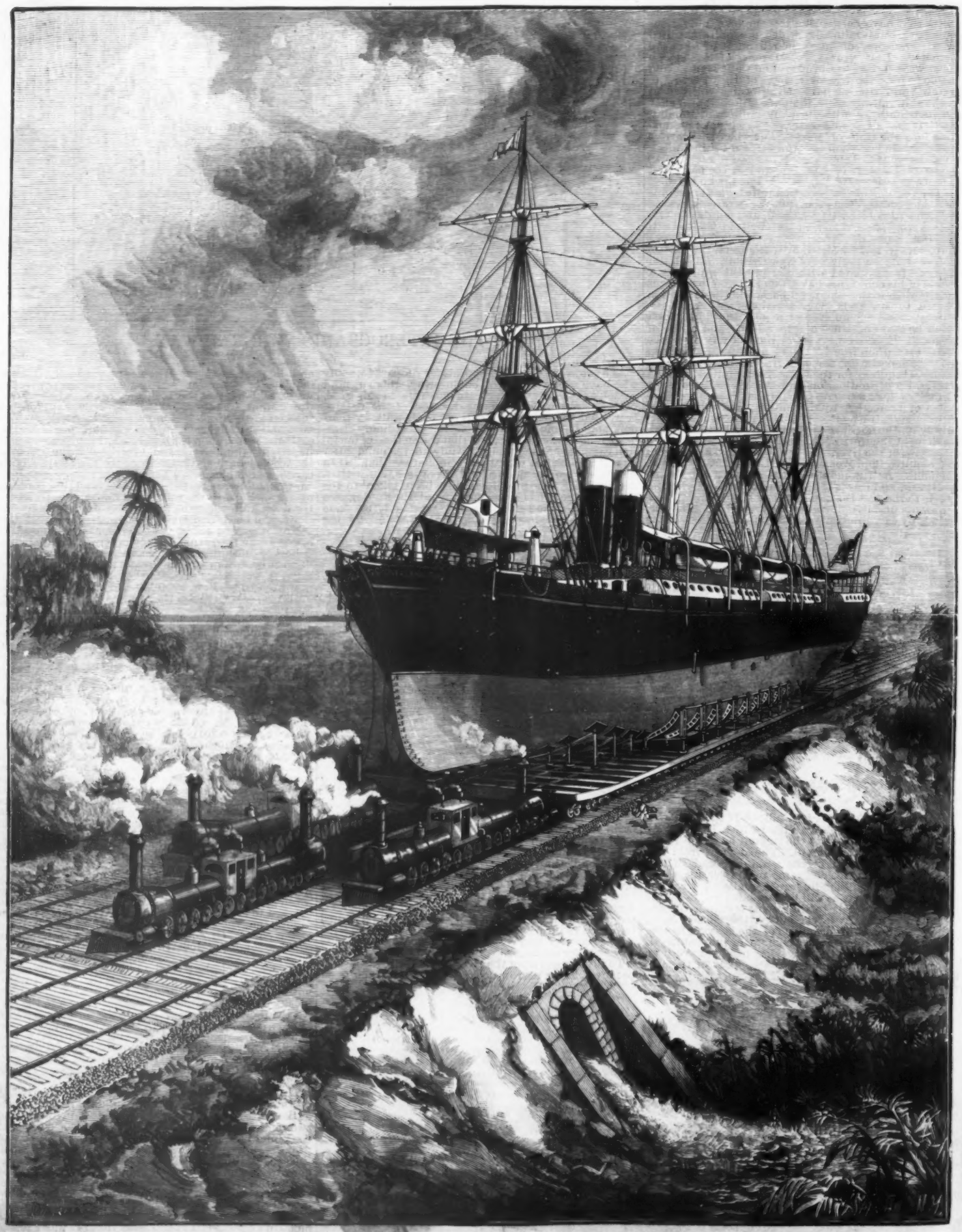


FIG. 6.—THE INTEROCEANIC SHIP RAILWAY.—A STEAMER IN TRANSIT.

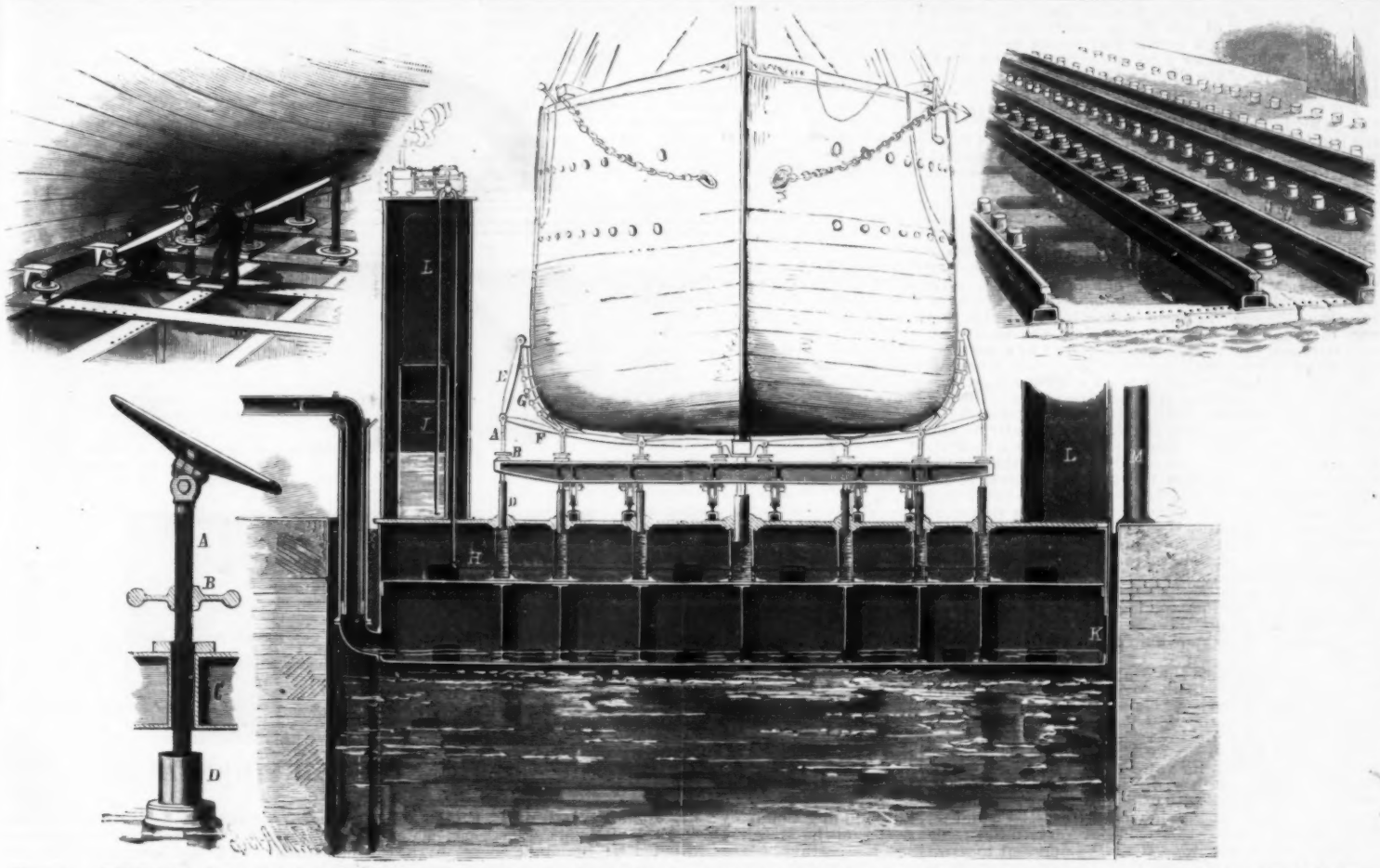


FIG. 7.—INTEROCEANIC SHIP RAILWAY.—SECTIONAL ELEVATION OF PONTOON AND RAILWAY CRADLE.

whereupon the water is exhausted from the presses, and the rams fall to their lowest position. When this is done the operation of raising the vessel is complete, and she is ready to be hauled ashore and to make for her land passage drawn by locomotives linked abreast. (See Fig. 6, from SCIENTIFIC AMERICAN.)

The details of the car and its general appearance are shown in Figs. 2, 3, and 4, which, we must remind our readers, are views sketched from a model constructed to demonstrate the general idea and the practicability of the scheme, and not to illustrate the precise arrangement which will be finally adopted. The main girders all run crosswise, the longitudinal strength being supplied by the road bed, and to a certain extent by the ship itself. As we have already explained, the weight of the vessel is first distributed in equal parts over the cross lines of presses, and then it is transferred to the girders, and through them to the springs and the wheels. Thus each wheel has an equal load, which in practice will be 8 or 9 tons with the largest ships it is proposed to deal with. Each wheel is carried on an independent axis (Fig. 4), and four of them are grouped together on each track between the adjacent girders. There is no swiveling arrangement of any kind, as the line is free from curves from end to end. Each wheel has a powerful spring which will require a pressure of 20 tons to close it through its whole range of 6 in., and which under its normal load will have a range of 3 in. both ways. Thus between the blocks and the ground there will be an elastic cushion upon which the ship

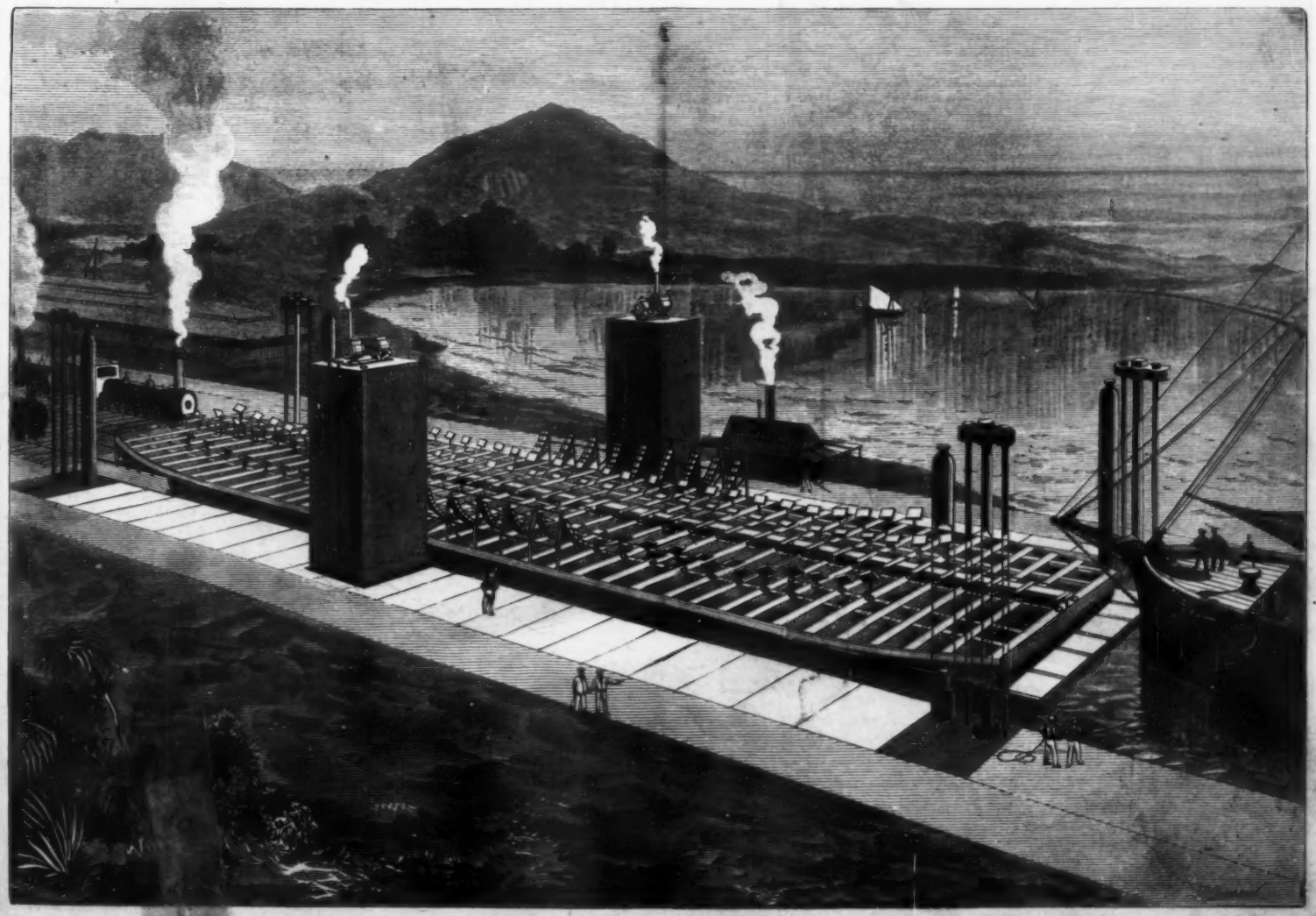


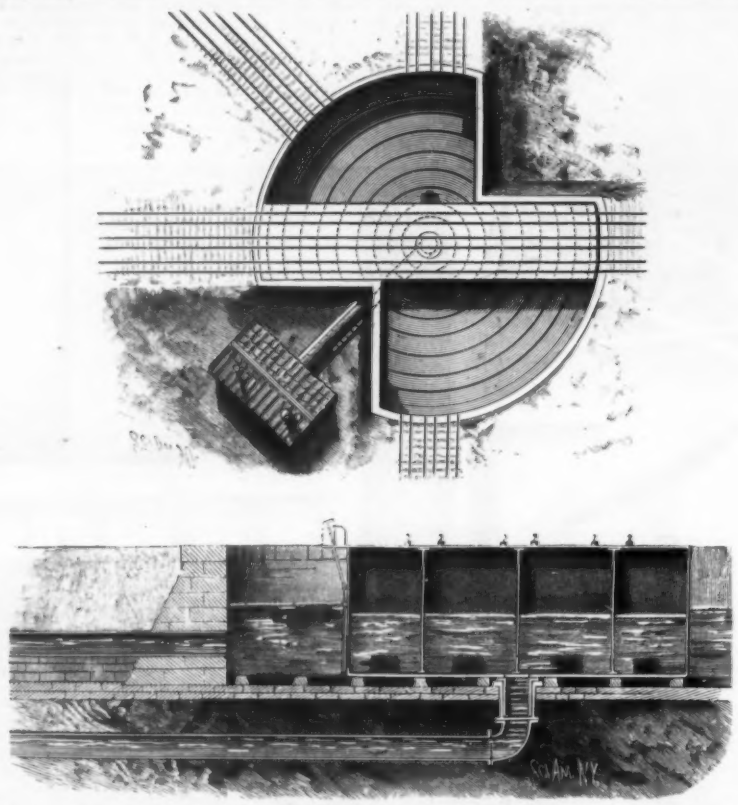
FIG. 8.—THE INTEROCEANIC SHIP RAILWAY.—THE LIFTING PONTOON AND RAILWAY CRADLE.

ean lie, securely protected from all shocks and vibrations. The faces of the blocks are likewise rubber lined, to give them a gentle and secure hold, while amidships the exterior rows are articulated together, to fit the curve of the ship, and to give her extra stability against wind pressure.

The railway will have three tracks of the usual gauge of 4 ft. 8½ in.; and will be built on straight lines. It is not possible to find one straight line over the 134 miles which separates the two oceans, neither is it practicable to take a carriage more than 400 ft. long round curves of less than 20 miles radius. In one part of the route the railway follows a succession of broad valleys, flanked by ranges of hills or spurs of the Sierra Madre; and to pass from one valley to another, or from one plain to another, it is necessary at five points to make sudden deflections. These will be effected by floating turntables, which constitute one of the most novel features of the whole undertaking. See Figs. 5, 9, 10, 11. The difference between a floating turntable and one of ordinary construction is that the usual pair of girders carrying the track are replaced by a pontoon, and the pit is filled with water. The pontoon is mounted on a central pivot, and runs on a circular way, just as usual. When a car is approaching, water is allowed to enter the pontoon, until it is firmly grounded and can support the weight of the ship as efficiently as any other part of the road. The car is then drawn on to it, and a centrifugal pump is set to work to withdraw the water from the pontoon through the central pivot. When the weight of the pontoon and its load is just waterborne, the table is rotated by steam power, to bring the rails opposite the new track, when the pontoon is again grounded and the car continues its journey. It is intended that some or all of the turntables shall have several tracks branching from them; these will form sidings into which a ship can be drawn, to allow it to pass another coming in the opposite direction. The sidings may also be used as dry docks, for the scraping, painting, and calking of the hulls of vessels.

We have thus traced the course of a vessel through the Gulf of Mexico, up the river Coatzacoalcos, on to the pontoon and the car, thence over the railway and its five turntables, and now it approaches the Pacific Ocean, where by an inversion of the process by which it was raised it is again lowered into its natural element, and continues its voyage to its destination. Of the practicability of these operations we shall say little, because our readers, with the illustrations of the apparatus before them, can judge for themselves, and we have already treated this point at very considerable length in previous issues. It will be sufficient to recall a few of the names of those who have borne unanimous testimony to the fact that there is in the problem no mechanical difficulty which cannot be solved. Sir E. J. Reed; Mr. Nathaniel Barnaby, Chief Constructor to the British Navy; Mr. William John, of the Barrow Shipbuilding Company; Mr. John Fowler; Mr. C. F. Lyster, of the Mersey Dock Estate; Messrs. Emerson and Murgatroyd, who constructed the hydraulic docks at Malta and Bombay; Mr. Leader Williams, engineer to the Manchester Ship Canal; Mr. B. Baker, engineer to the Forth Bridge; Professor Elgar, Mr. Martell, of Lloyd's, and a number of eminent American engineers, have given unanimous testimony to the feasibility of the scheme, and a committee of the United States Senate, after a long and exhaustive inquiry, summed up the case as follows: "The testimony upon the subject is so overwhelming and conclusive in its character, that the committee has no hesitation in reporting that the construction of a ship railway and its successful operation are entirely practicable."

Such a verdict by an intelligent tribunal settles all



Figs. 9 and 10.—ILLUSTRATIONS OF THE TURNTABLE.

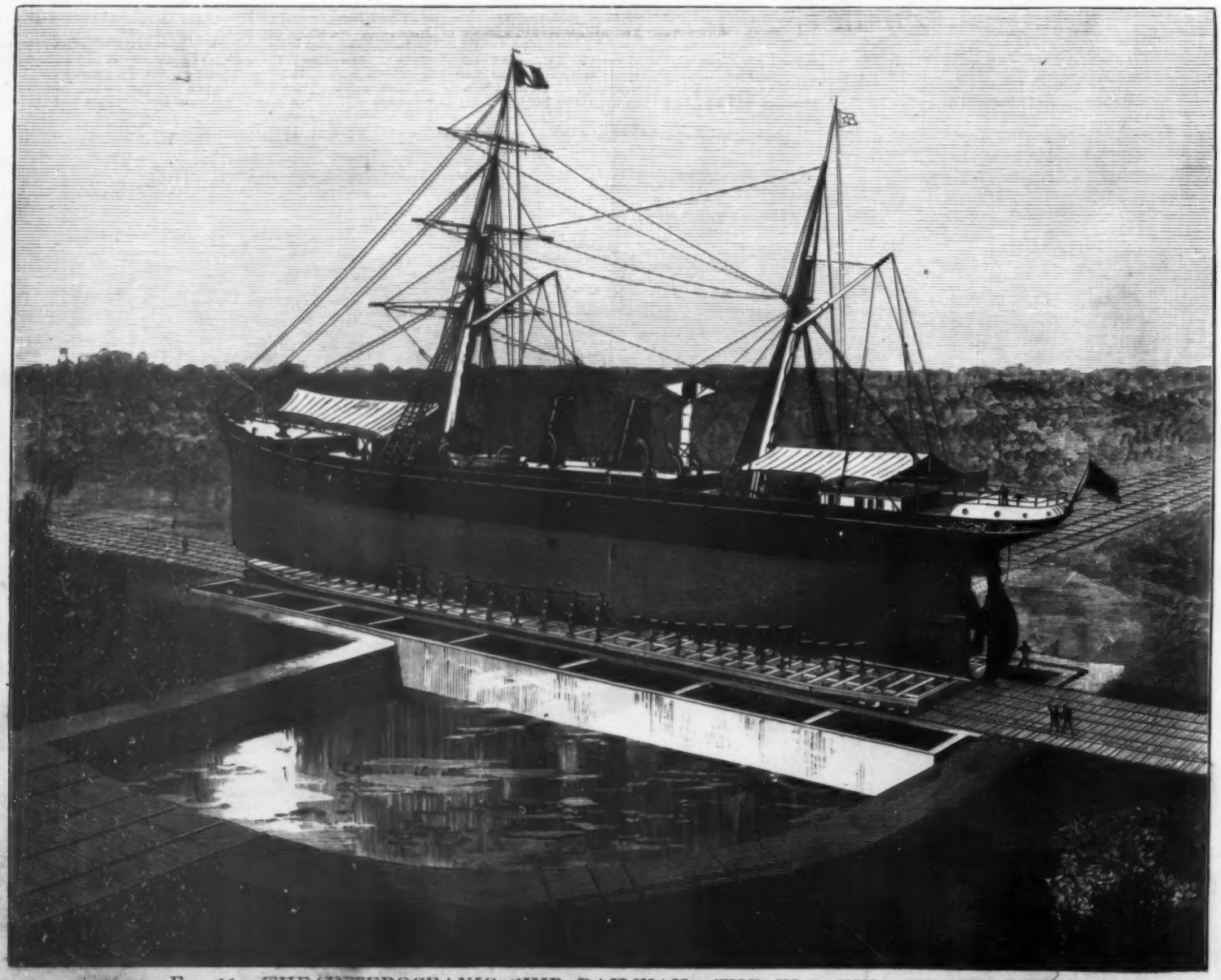


Fig. 11.—THE INTEROCEANIC SHIP RAILWAY.—THE FLOATING TURNTABLE.

doubt as to the competence of engineering skill to handle a laden ship with safety when out of the water, and it remains to inquire whether there is a prospect of sufficient trade to pay interest on the capital of ten millions sterling, which, it is estimated, the undertaking will require. We have already given details of the saving in distance the railway will effect on many routes, and it is confidently expected by its promoters that it will attract to itself a large proportion of the heavy trade on all lines now following longer tracks. Of course the competition of the Panama Canal must not be overlooked, but if Captain Eads is successful in obtaining pecuniary support when he places his project before the public, the railway will have been in working order some time before the canal is opened, and this together with the great advantages it offers to all kinds of shipping, and particularly to sailing craft, should be a great point in its favor, and should secure to it the lion's share of the trade. The Nicaraguan Canal, which it was announced was to be constructed by the United States Government, now appears to be to a great extent only a paper project, and it is by no means sure that it will receive the sanction of both branches of the legislature. Local patriotism also, in spite of trade being essentially cosmopolitan, may be confidently expected to rally the whole Mississippi Valley at the back of Mr. Eads, as there is probably not a child upon the length of that most magnificent water system who has not heard of his achievements in the improvement of its navigation. In 1879 an estimate was made by Mr. Joseph Nimmo, chief of the United States Bureau of Statistics, of the commerce which would have crossed the isthmus in that year if there had been suitable means of transit for it, and he found that the total amounted to 3,000,000 tons. Since then great advances have been made in trade, at least as regards its volume. The amount of traffic between the Pacific coast and foreign countries east of Cape Horn was estimated in 1879 at 551,929 tons, while in 1882 it actually reached 1,423,737 tons, including 900,000 tons of cereals. In 1882 the earnings of the grain fleet of the Pacific coast with Europe was over 3,000,000*l.*, and the earnings from the through freights between San Francisco and New York over the transcontinental railroad lines was more than this sum. About 25 per cent. of the business between the United Kingdom and the East Indies is carried in sailing ships around the Cape of Good hope, and of the 800,000 tons thus shipped it is expected that a portion will find a more expeditious journey by Tehuantepec, particularly as the winds are favorable by that route.

The following is a detailed estimate, prepared by the promoters of the railway, of the tonnage which they expect to be available on the railway in 1889:

Tonnage expected over the Ship Railway in 1889.

PRESENT ROUTES OF COMMERCE.	Actual Tonnage Carried on Routes longer than via Tehuantepec.	Estimated from Rate of Increase from 1879 to 1883, and from New Business to be Developed.
	Tons, 1883.	Tons, 1889.
1. Panama Railroad	77,958	60,000
2. United States Pacific Coast with Atlantic *via* Cape Horn	237,341	359,081
3. Atlantic Ports with countries west of Cape Horn	349,454	489,135
4. United States Pacific Coast with foreign countries east of Cape Horn	1,423,737	2,135,605
5. European countries with countries west of Cape Horn	1,828,621	2,285,776
6. British Columbia, Pacific Coast, with Europe	125,000	235,000
7. Slow bulky freights now going over Transcontinental lines	400,000	600,000
8. Fifty per cent. of tonnage now going from Asiatic countries to Europe *via* Cape of Good Hope	400,000	400,000
9. New trade to be developed by Ship Railway between Gulf ports of United States and Mexico, and the Pacific Ocean	..	1,000,000
	4,842,111	7,564,597

This is confirmed by the fact that Paris Interoceanic Canal Congress, held in 1879, estimated that in 1889 the traffic would amount to 7,250,000 tons. This expense of working the railway cannot be great. There will be no terminal charges, no transshipment, nor any handling of the goods. The accounts will be of the simplest kind, and from the moderate speed and the solid construction of the permanent way the charges for management and depreciation must necessarily be small. It is assumed that 40 per cent. of the gross receipts would cover the working expenses. Therefore, if the railway had a capital of 15 millions sterling, a toll of 3 dols. per ton on 6,000,000 tons would produce a profit of 2,160,000*l.*, or 14¼ per cent.; a toll of 2 dols. would yield 9·6 per cent.

We have now considered the geographical, structural, and commerical aspects of the ship railway. We have seen that it stands central to many of the world's busiest marts, and furnishes not only the shortest but the quickest route between the east and west. Unlike the American transcontinental lines, it does not climb thousands of feet into cloudland, to descend again by devious paths and formidable gradients, but it pursues a nearly direct course from ocean to ocean with an inclination of only a few feet to the mile. The breezes carry the commerce of the Atlantic to its very portal, while the Gulf Stream will drift the eastward bound argosy 90 miles a day without assistance from sail or steam. Near to one end there debouches the great Mississippi, with its length of 165,000 miles, including trunk and branches, which is bordered the whole distance with the shrewdest and most enterprising race in the world, already fretting within the limits of its almost boundless country, and beginning to explore the markets of the Old World in search of an outlet for its manufactured products. At the other end lies the Pacific coast, still in the infancy of its development, but already able to feed millions besides its own inhabitants, while away in the distance stand China, where France is wasting blood and treasure to gain a foothold for her trade, and Australasia, where three great European nations are scrambling for territory, which certainly will be no material gain to any of them for many years to come. Thus Tehuantepec stands a halfway house between the skill of western civilization and Oriental inertness; between lands where an unfavorable sky looks down on a reluctant soil, and those whose ground laughs into a yellow harvest; between those who must sell manufactured goods or starve, and those who produce fruit and cereals in great excess of their requirements. If a practicable channel had existed through the isthmus, it is certain that its possession would have been contested in many a bloody battle in which England, France, Holland, and Spain would have borne their parts in the roaring days when the Spanish Main furnished an outlet for the hot blood of maritime Europe. In comparison with this passage, the possession of Gibraltar would have been a bagatelle, because at the time of which we speak the idea of the comity of nations was only a phrase, and the country which found itself in a position to forestall its competitors in China and all the islands of the Pacific would have availed itself of its rich advantage, without regard to sentimental considerations. To-day trade is many thousands of times as great as it was then, and it remains to be seen whether Mr. Eads and his colleagues can open a way for it across this neck of land. To us the scheme appears perfectly feasible, and it only needs that it be carried out quickly and carefully. Commerce is timid; and a bad beginning might cast a shade on the undertaking that would turn the scale between it and its rival at Panama. The railway must not only be a success, but a success from the first moment it commences to work; and the inaugural car with its first ship must make its journey as safely and easily as the thousandth, and then it may be expected that day by day the marvelous procession will be kept up, and a feat will have been performed which will stand out in bold prominence, even in the crowded page of nineteenth century achievements.—*Engineering.*

In connection with the foregoing very excellent description of the Interoceanic Ship Railway, we give by way of additional illustration the series of engravings of the same subject which appeared in the SCIENTIFIC AMERICAN of Dec. 27, 1884. The original engravings from *Engineering* are Figs. 1, 2, 3, 4, 5, while those from the SCIENTIFIC AMERICAN are Figs. 6, 7, 8, 9, 10, 11. Some additional particulars by way of description are also given in the SCIENTIFIC AMERICAN of the above date.

BALANCING THE RECIPROCATING PARTS OF STEAM ENGINES.

To the Editor of the Scientific American:

In the SCIENTIFIC AMERICAN SUPPLEMENT of June 16, 1883, there was published an article entitled "Causes of Vibrations in Bridges," etc., since incorporated in a pamphlet on the "Properties of Rotating Bodies," and in turn confirmed, in part, by Mr. J. C. Hoadley, and antagonized by Mr. Frank H. Ball, in the *American Machinist.* After a careful review of the paper of Mr. Hoadley on the "Balancing of the Running Parts of Steam Engines" we are, even more than at first, impressed by the accuracy of his conclusions.

Mr. Hoadley says: "It may be remarked in passing, that the throw of any unbalanced rotating mass is toward the *light* side of the mass, and is nothing else than the effort of the mass to revolve about an imaginary axis passing through its own center of gravity, which is one side of the rigid axis of rotation and always on the heavy side of the revolving mass, and to bring this imaginary axis to coincide with the rigid axis."

When we first read the above paragraph from Mr. Hoadley, we had no difficulty in understanding his meaning, and now are surprised that Mr. Ball or any one else should misunderstand him. It is fair to infer that Mr. Hoadley based his proposition upon infinite velocity of rotation, and that, knowing by experiment that journals, as of a shaft supporting an unbalanced wheel, would be abraded or worn on portions coinciding with the light part of the wheel, the center of gravity and the rigid axis would eventually coincide. Invert the latter member of the sentence, and read, *The rigid axis will coincide with the center of gravity,* and his meaning is not changed. Infinite velocities only were theoretically considered by Mr. Hoadley, and the pamphlet which he quoted, and which Mr. Ball so abundantly combats.

The above is introductory to a proposition, in which we concur with Mr. Hoadley, that the reciprocating parts of an engine cannot be balanced by a counterweight in a rotating part. Mr. Hoadley simply and forcibly illustrates the proposition thus: "A crank disk affords satisfactory facilities for counterbalancing the crank, crank pin, and that portion of the connecting rod which shares the rotary motion of the crank. Double crank disks are still better in this respect. The counterbalance for the connecting-rod should be in the plane of oscillation of the rod—of revolution of the crank-pin end—but that is impossible. The best thing possible is to divide the balance weights between two crank disks, and the next best thing is to put the proper weight upon a single crank disk or upon a counterbalance cast with the crank. The connecting rod comes under the head of mixed forces. Its whole weight exerts reciprocatory force, and should be added to the weight of the piston, piston rod, and crosshead, which together constitute the reciprocating parts of an ordinary horizontal engine. These parts must remain unbalanced, unless equal masses can be set in equal and opposite motion, as in the Wells engine; but they can be rendered harmless, and even useful, by judicious management of compression and lead."

Mr. Ball evinces an earnest desire that some one should reply to him, and transfers his hostility from Mr. Hoadley to us, with a hint in his conclusion that the reply is expected from us. Preparatory to that reply, he desires us to review his article in opposition to Mr. Hoadley's theories. We sincerely regret that the words "hostility" and "antagonism" should ever have to be used to characterize the spirit of those who, like Mr. Ball, claim to appear "in the interests of science." But intolerance and acerbity are found in all ranks, notwithstanding the fact, which is patent to all, that more can be accomplished by amity. We well remember when Father Secchi came to America, and with his quick mind for generalizing and using all he saw, grasped that which his American fellow savants either knew not how to use or had neglected to use. After he went home and published his deductions, he was roundly abused because he had vaulted above those who should have been unselfish enough to "look through his eyes." If Mr. Ball would endeavor to understand Mr. Hoadley, all his objections would be answered.

Agreeably to his desire, we have reviewed his reply to Mr. Hoadley, and have also with equal care reviewed Mr. Hoadley's paper. While we have no difficulty in understanding the latter, we are utterly at a loss to see what Mr. Ball is trying to arrive at, at points where he assumes the most importance. Rotating bodies and revolving bodies seem to be synonymous in his mind; thus all his illustrations are so confused that without a glossary it would be impossible to get on common ground with him. An article in the SCIENTIFIC AMERICAN SUPPLEMENT, No. 368, would help him. He appears in one instance to try to illustrate a case of rotation by citing the conduct of the moon in its movement around the earth. The moon is essentially a revolving body, like a governor ball. It has a center of revolution, but no axis of rotation. Again, it is a particle of a rotating mass—consisting of the earth and moon—whose axis of rotation is within the earth, and situated just where it disproves some things which Mr. Ball is frantically desirous of substantiating. His is not the first example of distraction arising from lunar influences.

Mr. Ball reports an experiment in balancing the reciprocating parts of a steam engine, in which the whole western end of the State of Pennsylvania was shaken. We are almost surprised at that—not at the extent of territory, but at the smallness of area shaken. But perhaps there are States yet to hear from. According to the law of conservation of force, the whole earth should have been shaken. He makes merry over our confessed inability to compute the remote influences of vibrations; but can he, when he leaps from the earth or alights upon it, compute the values of resultant motions through their never ending trains? In the SCIENTIFIC AMERICAN SUPPLEMENT, No. 381, he will see something interesting on that point. Your pages have from time to time answered these inquiries by many able writers.

Mr. Ball writes in a spirit of impatience about the length of time he has been waiting for a reply. He may comfort himself with the assurance that he had not been unnoticed by us. But we forebore, having in mind the chalked injunction over the door of a music hall in a mining town, where an amateur pianist, with strenuous endeavor, was trying to entertain the crowd—"Don't shoot him, he's doing the best he can." Meanwhile, we trust he will continue to hope that some one will jump into the arena, and relieve him of the "scientific" (?) chip which he carries on his shoulder.

The mind is not puzzled to apprehend correctly the operation of a body rotating in space, and can easily comprehend the fact that it will rotate upon its center of gravity. It can also easily be understood that in an unsymmetrical rotating body the point of greatest distance from the center of rotation is the point of greatest deficiency of weight. The forces which produce the phenomena are mathematically tangible, and can be integrated in any practical or hypothetical case. An admirable analysis of rotary motion was published by Gen. J. G. Barnard in the *American Journal of Education,* June, 1857. The masterly manner in which he handles the subject excites the belief that accomplished military men, from Cæsar down to Gen. Barnard, are likely to be profound mathematicians. We commend the work to Mr. Ball.

When, however, a rotating body is constrained from rotating upon its center of gravity, by the huge mass of a lathe bed or other incumbrance, such as indicated by Mr. Ball, the lathe is not only shaken, but the building, to its foundations and throughout its thousand connections, with the earth or otherwise, is interminably shaken. So the point of greatest prominence in the rotating wheel which he has under consideration will be found by turns to be at various points in the circumference, varying with variations in speed and constraint. The elements which enter into this problem are so multiplex as to "defy computation." No finite mind can integrate them, and Mr. Ball is unkind in throwing his cold ridicule upon an ignorant world, while he stands by in august omniscience and withholds the feast for which his fellows hunger. In the SCIENTIFIC AMERICAN SUPPLEMENT, No. 389, there is an article on "Vibrations in Bridges" which may interest those who give this subject attention.

There is so much misapprehension regarding the conduct of rotating bodies, that no one ought to be overconfident of a premise without careful experiment, supported as far as possible by mathematical demonstration. There are surprises at every turn. In the SCIENTIFIC AMERICAN for Oct. 4, 1879, there is an illustrated article by H. J. M. Mattis, which is replete with interest. It is much to be regretted that Mr. Mattis did not contribute more in the same direction.

We think we have made enough of citations to sources to information to assist Mr. Ball to a better knowledge of the subject upon which he writes; and if he will come to Defiance, where our doors are open and exhibitions free, he may see many things which will surprise and instruct. He will learn to reason step by step, and a little more carefully by analogy, lest he again find himself turned around in his circle of investigation. His charts appear, in the main, to be right; but he seems to have failed to steer by them. Like the pilot who "passed the north star an hour ago," he fails to see that it is his ship, and not the illimitable universe, that has turned end for end.

We will not "call in our books," but will continue to furnish them to all who wish something on the "Art of Balancing." Another and larger edition is preparing.

"Science moves, but slowly slowly,
Creeping on from point to point."

DEFIANCE MACHINE WORKS, Defiance, Ohio,
CHARLES SEYMOUR, *Supt.*

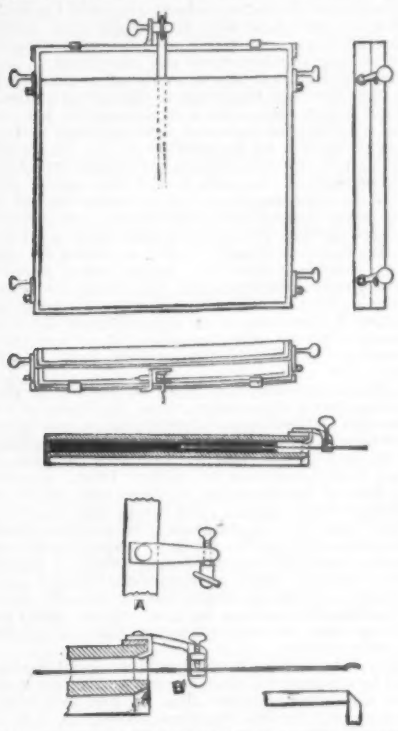
Feb., 1885.

[Continued from Supplement, No. 478, page 7624.]

THE ELECTROMETALLURGIC TREATMENT OF COPPER MATTE FOR THE EXTRACTION OF COPPER.

The Anodes.—The anodes are formed by the matte, which is obtained directly from the fusion of the ores and run into cast iron moulds so as to form plates 30 × 30 × 1 inches in dimensions. The melting is done in a small smelting furnace, with blast. This receives about 15 tons of ore every 24 hours, and produces about 50 plates, each weighing 176 pounds.

In order to connect the anodes in the refining works



Figs. 1 and 2.—DETAILS OF ONE OF THE ANODES.

they are cast with two lugs, by means of which they are suspended from the copper bars that conduct the current. This very simple method is impracticable when the anodes are formed of metallic sulphides, since these are very fragile. In this case elastic bars of copper are inserted in the liquid matte, and become firmly attached thereto when the latter cools. This secures a perfect contact.

In the beginning, the moulding of the anodes (Figs. 1 and 2) presented certain difficulties, due to the very unequal shrinkage of the sulphides, the consequence being a breakage of the plates during their cooling. After several experiments, it was found that a matte containing from 20 to 35 per cent. of copper, and a homogeneous cooling under shelter from the air, were the best conditions. In spite of this, the waste is still great, although that is not of much consequence, since the pieces are put to use, as will be seen further along. It has been proposed several times to form the anodes of the pieces of ore themselves placed in boxes having a porous diaphragm, or in wooden gratings with bars so closely set as to allow no dust to escape. The idea

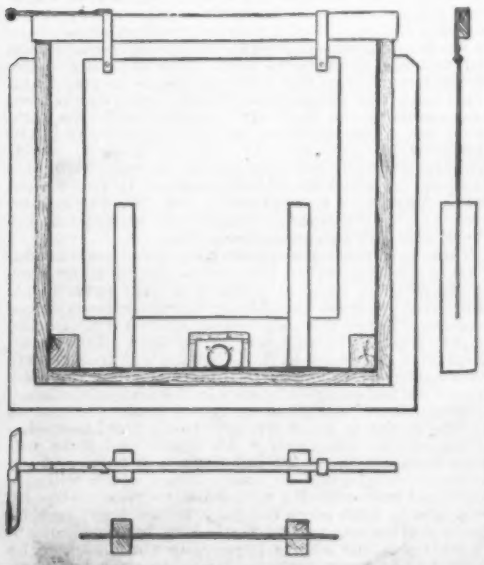


Fig. 3.—DETAILS OF ONE OF THE CATHODES.

has also been suggested to mix bits of carbon with the ore in order to increase the conductivity of the anodes, which, in both cases, would have to be connected with the conductor by means of blocks of lead or carbon. These and other similar methods have been tried, and we are convinced that they are impracticable in our industry on a large scale. All such projects are due to the erroneous idea that is held in regard to the electrolysis of metallic sulphides. According to this manner of seeing, the electric current produces acid and oxygen all around the anode, and it is therefore but natural to plunge the ores into this zone of oxidation in order that they may be dissolved. This is true when the potential between the electrodes is sufficient to decompose the electrolyte used; but in this case, the ores, not forming a true electric couple, would be affected to only a small degree by the acid and oxygen, and the disengagement of the latter is a clear proof that it is not acting upon the anodes. If, on the contrary, we operate with a low potential, the electric action limits itself to the pieces of ore that touch the blocks of lead or carbon, and through this very imperfect contact the resistance does not gain much.

It would be better to employ plates of ore compress-

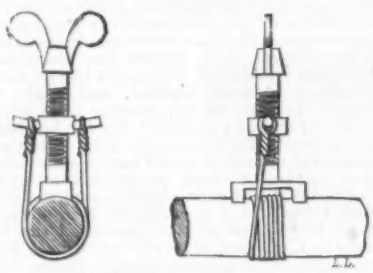


Fig. 4.—SCREW FOR ATTACHING THE ELECTRODES TO THE CONDUCTOR.

ed at a high pressure, but up to the present no satisfactory results have been obtained in this direction.

The electric action decomposes the mattes regularly over their whole surface, so that after a long operation a transverse section reveals a series of very thin layers that are superposed and may be easily separated. Analysis shows that the external layers are the richest in sulphur, and that they contain as much as 85 per cent. of it. The remains of the anodes, after the extraction of the sulphur, are put into the furnace again.

The Cathodes.—The cathodes are made of plates of very thin copper 27·5 × 27·5 × 0·1 inches in dimensions. To keep them from touching the anodes they are set into two wooden uprights, and are suspended from a bar by means of two bands, one of which communicates with the conductor. The details of the arrangement are shown in Fig. 3. As soon as a sufficient deposit has formed, the wooden uprights can be dispensed with, since the plate then has sufficient stiffness to allow it to remain suspended without danger of contact. The end of the band that connects with the conductor is bent at right angles, and slightly curved and adjusted to the bar that leads the current. To this it is attached by flexible copper wire wound spirally and by a screw whose structure is shown in Fig. 4. The copper is allowed to deposit until it has acquired a thickness of about two-tenths of an inch measured at the edge. After this the plates are taken out, folded thrice, and delivered to commerce.

The conductors are formed of very flexible bars of copper about one inch in diameter. The conductor is connected with the cathodes in the same way as with the anodes. It is not a very simple way, but it is the best that has as yet been found to secure a good contact—a very essential matter, so as not to have very unequal deposits on the plates and loss of current due to a heating of the contacts.

The Electrolytes.—We have stated above that for the separation of the two parts of iron contained in the anodes, it is necessary to employ nearly three parts of copper in the form of sulphate. To produce these large quantities of sulphate, we employ very rich ores and mattes, and roast them in a reverberatory furnace. The roasting is so performed as to secure oxides rather than

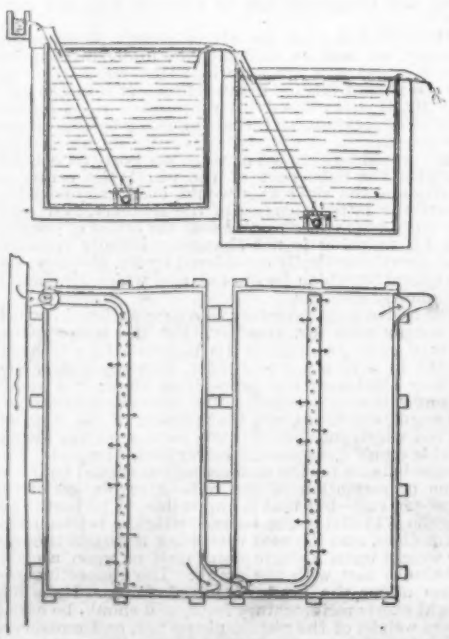


Fig. 5.—PLAN AND SECTION OF THE BACKS.

sulphates, because the iron oxide, not being soluble in dilute sulphuric acid, there forms very little iron sulphate in the solution. The products of the roasting are placed in leaden receptacles of wide surface, in order to be submitted to the action of dilute sulphuric acid. In this way are prepared the electrolytes that serve to fill the backs. Once prepared, these solutions circulate through the roasted substances for the purpose of keeping their quantity of copper constant. These solutions are not changed until the metal begins to deposit in a pulverulent state, and hydrogen begins to be given off. After the extraction of the copper, the residua of the roasted ore are put into the smelting furnace again.

The Backs.—Our electrolytic backs are of wood lined with lead, and are 6·5 × 3 × 1·25 feet in dimensions. The details of one of them may be seen in Figs. 5 and 6.

The Circulation.—A good circulation of the electrolytes is one of the most important conditions in a regular electrometallurgic operation, and the success of the process depends in great part upon it. The liquid at rest tends continually to supersaturate itself at the bottom and to become impoverished in the higher region of the voltameters. The difference in resistances be-

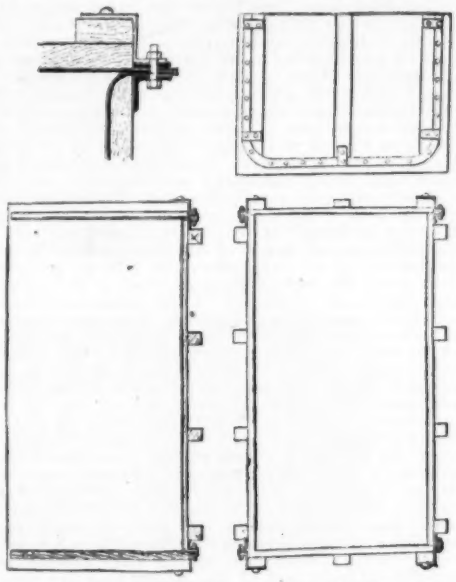


Fig. 6.—DETAILS OF THE BACKS.

tween the two layers causes the greater part of the copper to precipitate in the form of tubercles and granules, while the deposit above is very thin and often pulverulent and black. An active circulation obviates all this.

For a good circulation, the backs must be arranged in the form of a cascade, the fall of each being about 0·15 per cent. They are united in series of six. The liquid, placed in an elevated reservoir, is introduced into the bottom of vessel No. 1 (see Fig. 5), through a right-angled lead pipe having apertures in the part that rests upon the bottom of the back. A waste pipe placed on the opposite side carries the liquid to the second back, and so on. The upper edges of the anodes are 0·8 of an inch above the level of the liquid. The edges of the cathodes are, on the contrary, immersed beneath it.

The Dynamos.—In our present establishment there are 20 Siemens C18 dynamos that leave nothing to be desired as far as the regularity of their running is concerned. Every time that turbines revolving at high speed can be employed, it is easier to adapt the transmission to the dynamos, which run at a velocity of a thousand revolutions per minute; but when one has at his disposal a very low fall with a great volume of water, it is best to employ water wheels; and the proper speed is obtained by means of gearings and secondary transmissions, whose installation is always very cumbersome and more subject to damage. Under such circumstances, a dynamo running at a slight speed, and connected directly with the motor, would be of undoubted advantage.

Mode of Operating.—Having passed in review the various apparatus that are necessary for the electrometallurgic treatment of mattes, we shall now indicate the mode of operating adopted at the Sestri-Levante establishment for the production of two tons of electrolytic copper per day. The establishment is situated in the valley of the Bargonasco, upon the left bank of the torrent of the same name. The water necessary for the motive power is obtained from this stream. At present there are but two turbines of 50 H.P. each, and one of 75 H.P. The former run at a velocity of 350, and the latter at one of 280 revolutions per minute.

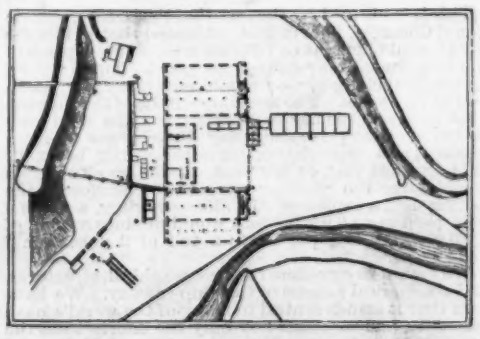


Fig. 7.—GENERAL PLAN OF THE ESTABLISHMENT.

The ores are derived from the Libiola, Galinaria, Monteloreto, and Bargone mines, in the vicinity of the establishment.

These ores consist or calcopyrites mixed with yellow pyrites of iron, and with a mean proportion of 15 per cent. of copper. These 15 per cent. ores are taken to the two smelting furnaces marked EF (Fig. 7). The charging is so performed as to obtain simple sulphides. The serpentine associated with the ore being a simple gangue, there is no need of flux for the regular running of the furnaces. Each furnace takes 15 tons per 24

hours, with a consumption of about 5 tons of 14 per cent. English coke, and produces 5 tons of matte, which is moulded in the form of plates with some loss in the moulding. These plates afterward go to the electrolytic backs under the sheds, G, H, I. The 20 dynamos are arranged in two batteries of 10 machines, and each dynamo is connected with 12 backs arranged for tension. A back is charged with 15 anodes, and 16 cathodes placed at a distance of about one-fifth of an inch between them. There is thus obtained an effective surface of nearly 2,1600 square feet.

The dynamo of the Siemens and Halske C18 type gives a current of 240 amperes, with a difference of potentials of 15 volts when the resistance of the external circuit is 0·0625 ohm, and the velocity is 950 revolutions per minute. The $12 \times 240 = 2,880$ amperes that traverse the bath would about correspond to a deposit of 180 pounds of copper per 24 hours, and per machine, did the electricity do no other work than that necessary for the deposition; but we know that a portion of the electric energy is employed in the reduction of the basic persulphate of iron. It became necessary, then, in order to compensate for such work, and to raise the production of copper to 220 pounds per day, to sensibly increase the intensity. This was done by greatly reducing the resistance of the external circuit. Such resistance would have to be ten times greater than that of the armature in order to obtain a good yield proportional to the motive power employed and to the electricity produced by the dynamo. On account of the great quantity of hydraulic power at our disposal, we did not attempt to be economical, but we especially desired to have great intensity; so we strove to produce an external resistance equal to that of the armature.

Our machine, under such conditions, gives a current of about 400 amperes with a difference of potentials of 11 volts measured at the terminals of the machine. This strong intensity does not affect the insulation of the armature. We are obliged to increase the resistance of one of the twelve backs, because the surface at our disposal, and the distance at which the electrodes are situated, produce a resistance in the external circuit which is less than we need. All this demonstrates that our plant may serve for a much greater production of copper if the machines are changed. Consequently, the cost of installation and the large capital employed for each ton of copper will be very appreciably reduced. The waste from melting is carried to the crusher, and, after being crushed, is put into the hydrosulphuric acid apparatus.

The following is the composition of the mattes: Cu = 34·7, Fe = 38·6, S = 25·3—this being the mean of several analyses. It will be seen from this that sulphur is not contained in them in large quantity, and that consequently the iron must be almost all in the state of FeS, and must therefore give, with dilute sulphuric acid, hydrosulphurous gas and sulphate of iron. This is, in fact, what happens; and so after this operation we shall have a matte much richer in copper, as shown by this analysis, viz., Cu = 52·1, Fe = 18·4, S = 26·3. This product goes to the reverberatory furnace in order to be roasted and be converted into sulphate for the formation of electrolytes. Instead of dilute sulphuric acid we use solutions that have served for electrolysis and that are acid enough to act upon the crushed mattes. The hydrosulphurous gas given off in the apparatus precipitates the small quantity of copper, reduces the ferric sulphates into ferrous sulphates, and, as the operation is performed with heat, concentrates the solution so that on coming from the apparatus it crystallizes. The excess of hydrosulphurous gas is led to a chimney, M, which also carries away all the other gas about the establishment.

The furnace, L, which is of ordinary construction, roasts 6 tons of products per 24 hours, and consumes 12 per cent. of coal.

In order to be sure of regularity in the operations, measurements must often be made, so as to find out what variations the electric constants are undergoing, and such observations must be made as carefully as possible. In the beginning we used Deprez's amperemeter for measuring intensities, and his potentimeter for differences in potentials. But since the latter did not give the potentials below one volt, our measurements we limited to finding the electromotive power of the machine, while it is very useful to know and to follow the variations in potential for each special voltameter.

Current measurers only mark as high as 50 amperes, thus making it necessary, for the measurement of the highest intensities, to add a system of resistance derivations equal to that of the amperemeter, and to have recourse to commutators in order to remove the circuit from the apparatus. We consequently selected Siemens' torsion galvanometer, which much better answers the requirements of electrolytic measurements.

As for the economic part of the process, it would not be possible to give positive figures for each case, since

FIG. 9.

these depend upon a host of circumstances connected with the quality of the ore, with the motive power at one's disposal, to the location of the plant, etc.—*Condensed from a paper by G. Badia, in La Lumiere Electrique.*

SEPARATION AND DETERMINATION OF POTASH IN COMMERCIAL FERTILIZERS.*

BOIL 10 grms. of the fertilizer with 5 c. c. of strong hydrochloric acid and 300 to 400 c. c. of water for ten minutes. Cool the solution, and, without filtering, make it up to 1,000 c. c.; mix thoroughly, and filter through a dry filter.

Take an aliquot corresponding to 0·5 or 1·0 grm., dilute if necessary to about 150 c. c., heat to boiling, and precipitate the sulphuric acid with a slight excess of barium chloride solution. Without filtering add an excess of barium hydroxide, and heat again to boiling. Filter and wash, at first by decantation, until the washings are free from chlorides. Heat the filtrate nearly to boiling, and precipitate the barium salts with ammonium carbonate and a little ammonia solution. Filter and wash; evaporate filtrate and washings to dryness, and ignite *below a red heat* until the ammonium salts are removed and the organic matter is oxidized as completely as possible. The residue, consisting of chlorides of potassium and sodium, with some charcoal and possibly a little barium salt which escaped precipitation, is digested with hot water; a few drops of ammonium carbonate are added, and the solution filtered and washed. The filtrate and washings are again evaporated to dryness and ignited gently.

The mixed chlorides are dissolved in water, an amount of platinum tetrachloride solution is added more than sufficient to form the double salt with all the potash and *soda* present, and the solution is evaporated at or below 100° C. so nearly to dryness that it becomes solid on cooling. To the cold mass, 10 to 20 c. c. of strong alcohol (80 p. c. to 95 p. c.) are added, and the mass is well broken up with a stirring rod pestle. After standing 5 to 10 minutes the supernatant liquid, which must have a reddish color from excess of platinum tetrachloride, is poured on a filter; more alcohol is added to the mixture of the double salts, and the whole stirred and pulverized and washed by decantation until the washings are perfectly colorless.

The precipitate is then brought on the filter by means of a wash bottle containing alcohol. The salt is dried at 100° C., and weighed. After weighing, the salt is dissolved from the filter with hot water, and the filter is dried and weighed together with any platinum which may have been reduced in drying down the solution with platinum tetrachloride or other impurities. The actual potash is reckoned from the weight of the double chloride of potassium and platinum by multiplying by 0·19308.

Potassium chloride is reckoned from the double salt by multiplying by 0·3056. These factors are based on the following atomic weights:

Platinum	197·18
Potassium	39·13
Chlorine	35·46
Oxygen	16·00

* Methods adopted by the Association of Official Agricultural Chemists, for use during the season of 1884-85.—*Chem. News.*

FIG. 8.—INTERIOR VIEW OF ONE OF THE BUILDINGS.

ON JAPANESE TEA AND TOBACCO.

By J. TAKAYAMA.

THE tea-leaves are gathered in May, and quickly dried by exposure to air, and carefully sifted so as to separate dust and fragments of leaves. They are then subjected to the steaming. This is done by introducing the leaves into a wooden tub, the bottom of which is formed of bamboo meshes, the tub being placed on an iron pan filled with water and heated from below. After thirty minutes, when the steam rises up, the wooden cover is taken off, and the contents are thoroughly mixed so as to steam uniformly all the leaves. This done, the tub is covered again with the lid. This process is repeated, and finally the contents are taken out and cooled. There is a tendency in leaves to adhere to the bamboo rod during mixing.

The leaves are now sufficiently softened to be rolled up between the hands by a gentle rubbing, after which the leaves are subjected to drying. This operation is a most difficult one, inasmuch as the quality of the product depends in a great measure on the treatment which the leaves undergo during the operation, since it is during drying that that fine color becomes fixed, with simultaneous production of that delicate flavor and agreeable taste which are wanting in the original leaves; so that it requires excellent workmen, whose requisite skill is only attained after a long practice.

The drying is conducted in a shallow rectangular box, the bottom of which is made of a thick paper stiffened with starch. The box is placed over a copper-wire gauze supported by iron bars, which are provided across the furnace. The furnace is simply a rectangular box coated with clay, and has the depth of 2·5 shaku.

To begin the operation, first of all a charcoal fire is made in the furnace. The rectangular box is now placed over it, the leaves are next introduced into the box, and the workman continually rubs them between the hands, alternately tossing them up and letting them fall until they are nearly dried. Thus dried the leaves are further dried by keeping for a night in the same furnace after the charcoal fire is withdrawn. In large factories numbers of these furnaces are arranged in rows, and during the drying each furnace is attended by one workman.

The tea thus dried is, before it is sent to the market, subjected to sorting and sieving. The sorting simply consists in spreading out a certain quantity of tea upon a flat table, and in removing dust, stems, and other foreign matters by picking them up, which operation is usually done by women and girls. The sorted tea is then sieved.

The sieves of different meshes are distinguished from one another by the numbers 1, 2, 3, etc., and the number of sievings as well as the sieves used vary with the quality of the tea. Thus, in the case of coarse kinds, it is passed twice or thrice through each of 1 and 2, and in the best kinds only once through 2, 3, 4, and twice through 3, which has the meshes of nearly 3 millimeters. The tea thus prepared is preserved in earthenware or metallic pots, in order to preserve it from the moisture.

BLACK TEA.

Before intercourse with Western nations was opened this was scarcely known to us, but now at present it is manufactured, though to a very limited extent, for the purpose of exporting it to foreign countries.

The writer states the following description of the process to be due to the report published by order of the board for promotion of industry, agriculture, and commerce.

In preparing the black tea, the leaves from wild tea-plants, or those which are cultivated without much care, are used, otherwise there will not be much profit.

The leaves after gathering are scattered on a straw mat, and dried by exposure to air. They are then collected, and softened by tossing and clapping between the hands till they become adhesive. The leaves are then made into a number of balls, which are introduced into a large box, which is closed tightly and exposed to the sun for half an hour, when it is brought into the house, and allowed to lie in this state for one night.

The balls are then taken out, and subjected to the rolling and drying in the same way as in the preparation of green tea. During the operation the workman turns the mass so as to prevent it from being burnt. This process is continued until the leaves break very easily by simply pressing between the fingers, when they are considered to be perfectly dry. The tea thus produced is freed from impurities and stalks, and sepa-

rated into different kinds by passing through sieves having meshes of different size.

The specimens he chemically examined are all those prepared in the celebrated tea producing district Uji, and are supposed to be unadulterated.

The accompanying table gives the result of the analyses. On examining the table there seems to be no connection between commercial quality and chemical composition, but it is very interesting to observe how nearly the same is the amount of the constituents in all specimens; so that, in any instance, if we find some of the constituents, as ash, for instance, in quantity differing from those found in the table, we may consider such specimen being previously adulterated.

ANALYSIS OF JAPANESE TEAS.

Name.	Moisture.	Ash.			Organic Matter.			Total Extract.	Nitrogen.	Yens per Kin.
		Soluble.	Insoluble.	Total.	Soluble.	Insoluble.	Total.			
Shimonohaua	9·27	3 86	1·18	5·04	35·96	50·74	86·70	39·82	4·24	0·24
Toyokumo	9·97	3·74	1·20	4·94	37·06	46·03	85·09	42·70	4·14	0·25
Hochayen	9·38	2·66	2·72	5·38	34·14	51·10	85·24	36·80	3·90	0·50
Kiuimosato	7·66	4·35	1·26	5·61	38·40	48·33	86·73	42·75	—	1 25
Nagauotomo	8·71	4 28	1·69	5·97	37·32	48·00	85·32	41·60	5·37	1 50
Toyokage	8·81	3·88	1·68	5·56	40·40	45·23	85·63	44·28	—	2·50
Toyomaye	8·31	3·41	1·32	4·73	41·87	45·09	86·96	45·21	3·87	3·50
Giokuro	6·90	3·45	2·55	6 00	33·55	53·55	87·10	37·00	—	5·00

Theine.—He estimates this most important constituent of tea by the following method: 15 grms. of powdered tea are mixed with an equal amount of magnesia, and the mixture is boiled with water, filtered, and residue washed with hot water. The filtrate being evaporated to dryness is exhausted with hot benzole, and the extract is then evaporated and the residue is weighed. By this method he found 0·189 per cent. in *Nagauotomo*, and 0·207 per cent. in *Horiu*, all brought from Uji.

Tannin.—This is determined by a standard solution of plumbic acetate. In six specimens from Uji he found the following amounts: Toyokumo, 16 per cent.; Toyokage, 16·25 per cent.; Shimonohaua, 15·62 per cent.; Nagauotomo, 14·70 per cent.; Toyomaye, 16·70 per cent.; Hochayen, 16·12 per cent.

Gum.—Estimated by evaporating the aqueous extract of tea almost to dryness, treating the residue with methyl spirit, the extract evaporated to dryness, and the residue weighed, which after ignition is again weighed; the loss represents the gum. By this method he found the following amounts in the same specimens as above. Toyokumo, 13·72 per cent.; Toyokage, 9·75 per cent.; Shimonohaua, 12·32 per cent.; Nagauotomo, 10·10 per cent.; Toyomaye, 9·90 per cent.; Hochayen, 10·61 per cent.

ANALYSIS OF TEA ASH.

	Green Tea from Uji.		Black Tea from Settsu.	
	I.	II.	III.	IV.
Silica	8·91	6·19	5·01	4·61
Sulphuric acid	3·87	4·70	3·03	4·22
Phosphoric acid	16·62	17·02	21·87	19·77
Chlorine	1·62	1·95	1·26	1·04
Carbonic acid	7·82	9·45	6·23	7·02
Oxide of iron and alumina	8·21	9·06	6·35	7·96
Manganese sesquioxide	0·59	trace.	0·98	1·30
Lime	14·57	13·17	8·33	10·42
Magnesia	6·95	6·17	6·92	7·00
Soda	2·70	4·03	5·01	2·99
Potash	27·92	28·11	35·04	33·60
	99·78	99·86	100·03	99·93

JAPANESE TOBACCO.

There are various varieties of tobacco plant differing more or less in the form and size of the leaf, but those growing in this country are known as *Nicotiana Chinensis* and *Nicotiana Tabacum*, bearing a rose colored flower, and growing to the height of 3 to 5 feet. The tobacco plant is cultivated almost in every province, but the best leaves are produced in the provinces of Hizeu, Hitachi, Satsuma, and Nagato.

The mode of collecting the leaves varies in different places, but generally two or three small leaves, which are situated at the upper part of the stem, are first taken off by hand, and the remaining leaves, after being exposed to the sun for 3 to 5 days, are successively taken, three or four at a time. In Awa it is just reversed; the lower leaves, which are of inferior quality, are taken off at first in June, when the leaves are slightly yellowish, and the middle leaves, which form the best sorts, are collected after 13 or 14 days. In some places a second crop is obtained from new shoots, which, if properly cultivated, yield leaves which are not inferior to those of the first gathering.

The leaves thus collected are placed on a floor covered with a straw mat, allowed to remain for one or two days, when the mat is taken off; those which have assumed the melon-yellow color are sorted out and dried by exposure to air, while those still retaining the original color are kept in the same condition till the required color is developed.

The dried leaves are now packed and sent to market. According to Japanese fashion, tobacco for smoking purposes is cut into fine threads.

The methods he used for the determination of nicotine and organic acids are as follows:

1. *Nicotine.*—Ten grms. of powdered tobacco are made alkaline by ammonia, which is intended to displace nicotine. It is then extracted by ether, the extract evaporated to dryness, when a pasty residue of nicotine and a greenish yellow resinous body are obtained, from which nicotine is determined by standard sulphuric acid.

2. *Acetic Acid.*—Tobacco powder is moistened with water, and then ground with tartaric acid. The mass is exhausted with steam, which volatilizes acetic acid, and which is condensed by means of Liebig's condenser. The acid is determined by means of standard alkaline solution.

3. *Oxalic, Malic, and Citric Acids.*—Ten grms. of tobacco are moistened with hydric sulphate, the quantity to be used being previously calculated from the ash of the leaves. It is then exhausted with ether in a continuous distillation apparatus. The organic acids are dissolved in ether, and the operation is completed when a small quantity of ether, evaporated, does not leave any residue.

In order to extract the required acids, leaving the foreign bodies in ether solution, a few drops of water are added and the whole is shaken. The aqueous solution is separated from ether solution, and the water solution is neutralized by ammonia, and a few drops of acetic acid is added. Then the oxalic acid is precipitated by a dilute solution of calcic acetate, and determined.

To the filtrate a dilute solution of lead acetate is added until a permanent precipitate appears, and about 1 c. c. of the supernatant liquid is taken into a test-glass, and a drop of very dilute lead acetate solution is added; if the precipitate produced is not dissolved by addition of a few drops of acetic acid, then, after 1 c. c. taken is returned to the main portion, the addition of lead acetate is continued. This is repeated until a precipitate, produced by a new addition of lead acetate, is completely soluble in hydric acetate. Then it is filtered, washed with water containing a small quantity of lead acetate and acetic acid, and finally with alcohol at 36°. The washings are kept separate from the main filtrate. Citric acid is then determined from the lead oxide left after combustion of the precipitate. In the washings a small quantity of citric and malic acids is present; they are precipitated, after alcohol is expelled, by adding an excess of lead acetate, and their amounts are determined from the quantity of lead oxide, assuming the two acids to be present in equal proportions.

In the filtrate, malic acid is precipitated by adding an excess of lead acetate solution, and the precipitate is treated as in case of citric acid.

ANALYSIS OF TOBACCO LEAVES.

	Province of Production.			
	Nagato. Per cent.	Shimozuki. Per cent.	Settsu. Per cent.	Osumi. Per cent.
Water	6·41	10·01	7·63	13·18
Ash	15·76	8·45	20·71	9·80
Nicotine	2·45	3·02	3·92	1·89
Acetic acid	0·05	0·04	0·01	0·08
Oxalic "	trace.	0·27	0·25	trace.
Malic "	0 79	1·02	1·83	2·98
Citric "	0·52	0·59	0·92	0·89
Pectic "	1·24	5·84	7·42	2·35

	Province of Production.			
	Nagato.	Shimozuki.	Settsu.	Osumi.
Carbonic acid	10·20	15·40	10·20	14·86
Sulphuric "	4·75	3·40	2 02	5·52
Phosph. "	4·30	5·15	3·32	4·85
Chlorine	11·70	8·23	5·56	4·45
Silica	3 86	5·46	9·55	5·51
$Fe_2O_3+Al_2O_3$	3·80	2·60	8·17	9·15
Lime	33·12	22·92	23·45	21·95
Magnesia	7·98	6·57	8·02	6·78
Potash	13·78	25·52	27·51	24·49
Soda	6·11	4·18	3·82	1·90
	99·60	99·43	99·62	99·46

4. *Pectic Acid.*—Ten grms. of powdered tobacco are exhausted with alcohol at 36° containing one-fourth its volume of concentrated hydric chloride until the filtered liquid no longer contains lime. The residue is washed with alcohol so as to remove hydric chloride completely, and it is then treated with a solution containing a known quantity of ammonium oxalate, by which pectic acid is dissolved out. After two hours' digestion at 35°, it is filtered, the residue washed, the filtrate made to 1 liter, from which a known volume is measured out, and an excess of calcic acetate is added, when a white precipitate of oxalo-pectate of lime is formed, which is filtered on a weighed filter and weighed after drying at 100° C. This precipitate is then burnt, and the amount of lime formed is ascertained. The amount of pectic acid is then calculated from the following:

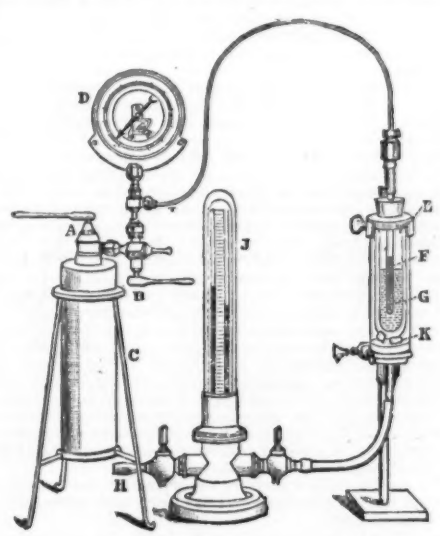
$$P=(B-C\tfrac{4}{7}A),$$

where A is the weight of ammonium oxalate, and B that of oxalo-pectate, and C the amount of lime formed on burning oxalo-pectate.—*Chem. News.*

RESEARCHES ON LIQUEFIED GASES.*

By Professor James Dewar, M.A., F.R.S.

The two Russian chemists, MM. Wroblewski and Olzewski, who have recently made such a splendid success in the production and maintenance of low temperature, have used in their researches an enlarged form of the well-known Cailletet apparatus; but for the purposes of lecture demonstration, which necessarily involves the projection on a screen of the actions taking place, the apparatus represented in the annexed woodcut is more readily and quickly handled, and enables comparatively large quantities of liquid oxygen to be produced. The arrangements will be at once understood on looking at the figure, which is taken from a photograph. The oxygen or air reservoir, C, is made of iron; it contains gas compressed for convenience to 150 atmospheres. A is the stopcock for regulating the pressure of the gas in the glass tube, F, and D is the pressure-manometer, the fine copper tube which connects the gas reservoir and the glass tube, F, being shown at I. The air-pump gauge is marked J, the tube leading to the double oscillating Bianchi being attached at H. The glass test-tube, G, which contains the liquid ethylene, solid carbonic acid, or liquid nitrous oxide, which is to be boiled *in vacuo*, is placed in the middle of a larger tube. It has holes, shown at E, in the upper part, so that the cool vapors in their course to the air-pump are forced to pass round the outside of the vessel and help to guard it from external radiation. The lower part of the outer cylinder is covered with pieces of chloride of calcium, shown at K. If a thermometer is used and a continuous supply of ethylene maintained, the India-rubber cork through which the tube, F, passes has two additional apertures for the purpose of inserting the respective tubes. When the pump has reduced the pressure to 25 mm., the ethylene has a temperature of about —140° C.; a pressure of between twenty and thirty atmospheres is then sufficient to produce liquid oxygen in the tube, F. The tube, F, is 5 mm. in diameter, and about 3 mm. thick in the walls, and when filled with fluid oxygen (for projection) holds at least 1·5 c. c. With such a quantity of fluid oxygen it is easy to show its ebullition at ordinary pressures, and by means of a thermo-junction to demonstrate the great reduction of temperature which is attendant on its change of state at atmospheric pressure.



Provided a supply of liquid ethylene can be had, there is no difficulty in repeating all the experiments of the Russian observers; but as this gas is troublesome to make in quantity, and cannot be bought like carbonic acid or nitrous oxide, such experiments necessitate a considerable sacrifice of time. It was, therefore, with considerable satisfaction that I observed the production of liquid oxygen by the use of solid carbonic acid, or preferably liquid nitrous oxide. When these substances are employed, and the pressure is reduced to about 25 mm., the temperature of —115° C. may be taken as that of the carbonic acid, and —125° C. as that of the nitrous oxide. As the critical point of oxygen, according to the Russian observers, is about —113° C., both these cooling agents may be said to lower the temperature sufficiently to produce liquid oxygen, provided a pressure of the gas above the critical pressure, which is 50 atmospheres, is at command. In any case, however, the temperature is near that of the critical point; and as it is difficult to maintain the pressure below about an inch of mercury, the temperature is apt to be rather above the respective temperatures of —115° C. and —125° C. In order to get liquefaction conveniently with either of these agents, it is necessary to work at a pressure of oxygen gas from 80 to 100 atmospheres, and to have the means of producing a sudden expansion when the compressed gas is cooled to the above mentioned temperatures. This is brought about by the use of an additional stop-cock, represented in the figure at B. During the expansion the stop-cock at A is closed, and the pressure manometer carefully observed.

No doubt liquid nitrous oxide is the most convenient substance to use as a cooling agent; but as it is apt to get superheated during the reduction of pressure, and boil over with explosive bursts of vapor, it is well to collect the fluid in a small flask of about 250 c. c. capacity, and to change it into the solid state by connecting the flask with the air pump, and then to use the substance in this form. The addition of alcohol or ether to the solid nitrous oxide makes the body more transparent, and thereby favors the observations.

It is evident that this apparatus enables the observer to determine the density of the fluid gases condensed in the tube, F; since he has only to measure the volume of fluid in F, and to collect, by means of the stop-cock, B, the whole volume of gas given by the fluid and condensed vapor, which gives an accurate determination of the total weight of substance distributed between fluid and vapor in the whole apparatus.

The amount of substance which is required to produce the vapor is easily found by observing the vapor pressure of the liquid gas before expanding it into gas for the volume measurement; and while keeping shut the stop-cock, B, by opening A suddenly until this pressure is just reached, and then instantly shutting off the receiver. If this volume of gas is now measured by opening B as before, the difference between the two volumes thus collected will correspond to the real

* A paper read at the Royal Institution of Great Britain.—*Chem. News.*

weight of substance in the liquid state. A rough experriment with oxygen near the critical point gave the density 0·65.

As to the most convenient substance for use as a cooling agent, I am still of the opinion that marsh gas would be the best; and I may take the opportunity of pointing out that the employment of this body was suggested by me in a communication made to the Chemical Section of the British Association in 1883.

The following extract from *Nature* of October 4, 1883, will prove that my experiments with liquid marsh gas were made a year in advance of those made recently by M. Cailletet* and M. Wroblewski†:

"Professor Dewar pointed out an important relation between the critical temperatures and pressures of volatile liquids and their molecular volumes. The ratio of the critical temperature to the critical pressure is proportional to the molecular volume, so that the determination of the critical temperature and pressure of a substance gives us a perfectly independent measure of the molecular volumes.

"Prof. Dewar pointed out the great advantage of employing a liquid of low critical temperature and pressure, such as liquid marsh gas, for producing exceedingly low temperature. He hoped to be able to approach the absolute zero by the evaporation of liquefied marsh gas, whose critical temperature was less than —100° C., and whose critical pressure was only 39 atmospheres."

I ought to mention that the marsh gas used in my experiments was made by the action of water on zinc methyl, and was therefore very pure, and that the observed critical pressure was not 39 atmospheres, but 47·6. The following table gives the value of the ratio of the absolute critical temperature to the critical pressure in the case of a number of substances. The values for ammonia, sulphureted hydrogen, cyanogen, marsh gas, and hydride of ethyl are new.

	T. Critical temperature.	P Critical pressure.	$\frac{T}{P}$
Chlorine.....Cl_2	141·0°	83·9	5·0
Hydrochloric acid..HCl	52·3	86·0	3·7
Oxygen.....O_2	—113·0	50·0	3·2
Water.....H_2O	370·0	195·5	3·3
Nitrogen.....N_2	—146·0	35·0	3·6
Hydrogen sulphide.H_2S	100·3	92·0	4·0
Ammonia.....H_3N	130·0	115·0	3·5
Diethylamine...$(C_2H_5)_2HN$	220·0	38·7	15·4
Nitrous oxide.....N_2O	35·4	75·0	4·1
Sulphurous acid...SO_2	155·4	78·9	5·4
Marsh gas.....CH_4	—99·5	50·0	3·5
Acetylene.....C_2H_2	37·0	68·0	4·5
Ethylene.....C_2H_4	10·1	51·0	5·5
Ethyl hydride.....C_2H_6	35·0	45·2	6·8
Amylene.....C_5H_{10}	191·6	33·9	13·7
Benzol.....C_6H_6	291·7	60·4	9·3
Chloroform.....$CHCl_3$	268·0	54·9	9·9
Carbon chloride....CCl_4	282·0	57·6	9·6
Carbonic acid.....CO_2	31·9	77·0	4·0
Bisulphide of carbon.CS_2	277·7	78·1	7·0
Cyanogen.....C_2N_2	124·0	61·7	6·4

A glance at the last column of the table shows that a large number of substances have at their respective critical temperatures simple volume relations. Thus hydrochloric acid, water, ammonia, and marsh gas, the four chemical substances from which the great majority of chemical compounds may be derived by processes of substitution, have nearly the same volume; while the more complex derivatives show an increased volume which bears a simple ratio to that of the typical body. As the critical pressures are not known with any great accuracy at present, it would be useless to discuss the results with any severity. All that can be inferred is that the subject is worthy of further investigation, and promises important generalization.

Sarrau (*Compt. Rend.*, 1882) deduced the critical temperatures and pressures of hydrogen, oxygen and nitrogen by the application of Clausius' formula to the experiments of Amagat; and it is interesting to compare his results with the experimental values.

Sarrau's Calculated Values.

	T. Critical temperature.	P Critical pressure.	$\frac{T}{P}$
Hydrogen.....	—174°	98·9	1·0
Oxygen.....	—105·4	48·7	3·4
Nitrogen.....	—124	42·1	3·5

It will be observed that the calculated critical temperatures of oxygen and nitrogen are remarkably near the truth, being respectively 8° and 22° too high. On the other hand, the values of the ratios of the calculated critical temperatures and pressures are almost identical with those obtained by direct experiment. The only peculiarity to be noted is in the case of hydrogen, which has such a high critical pressure and therefore leads to a remarkably small molecular volume at the critical point. If the values of the T ÷ P ratio be taken as proportional to the molecular volumes, then it is easy to infer the densities of the fluids at their respective critical temperatures, provided the density of one standard substance is known by experiment. The simple formula thus stated is—

$$\frac{S'}{S} = \frac{W^1}{W} = \frac{V}{W}$$

where S and S' are the specific gravities of two bodies, W and W' their molecular weights, and V and V' their molecular volumes. It will be convenient to take the density of carbonic acid at the critical point as the standard density to which the others can be referred. The density of carbonic acid under such conditions may be taken as 0·65.

Calculating with the above formula, the density of acetylene would be 0·32, whereas the experimental number of Anadell is 0·36. In the same way the density of hydrochloric acid is found to be 0·6, the true value being 0·61. The density of oxygen would be 0·63, and that of nitrogen 0·45. The calculated density of hydrogen at its critical point would be 0·12 if we assume the correctness of Sarrau's values for the critical temperature and pressure.

We may compare these values with the numbers obtained by Cailletet and Hautefeuille for the densities of oxygen, nitrogen, and hydrogen from their experiments on the density of liquid carbonic acid obtained from mixtures of this body with these gases. At the temperature of 0° C., the experiments found for oxygen, nitrogen, and hydrogen the respective values of 0·65, 0·37, and 0·025. It seems that the calculated values for oxygen and nitrogen are not very far wrong; but hydrogen is clearly incorrect. The explanation of this anomaly is probably to be found in the fact that the calculated molecular volume of hydrogen is wrong, and that instead of being unity on our scale it ought to be 3·5, like oxygen and nitrogen. In fact, the chemist would infer that, as the difference in the complexity of the molecular structure of hydrochloric acid, water, ammonia, and marsh gas does not affect the molecular volume under the conditions we are discussing, in all probability the value for hydrogen would be identical with that of the above mentioned bodies. If we adopt this view, and change the value of the $Tc \div Pc$ to 3·5, then the density of the fluid would become 0·034, which is in accordance with the experimental number of Cailletet and Hautefeuille.

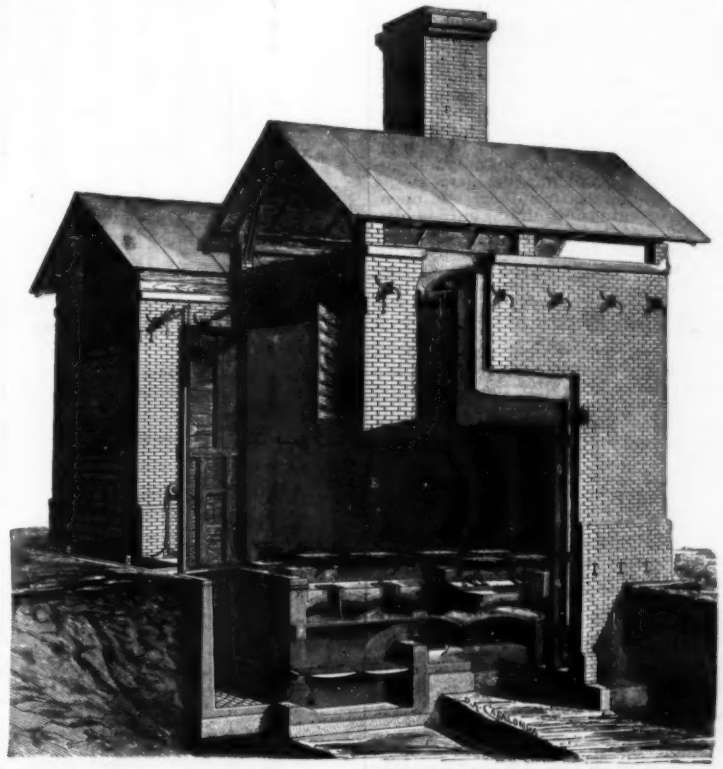
An accurate determination of the critical temperature and pressure of hydrogen, for which, judging from the success of the experiments of Olzewski, chemists will not have to wait long, will thus be of great interest.

* "Sur l'emploi du Formene pour la production des tres basses temperatures," *Comptes Rendus*, June 30, 1884.

† "Sur les propriétés du gaz des marais liquide, et sur son emploi comme refrigerant," *Comptes Rendus*, July 21, 1884.

ON THE DRYING OF WOOD.

THE drying of wood is an important operation that has been practiced for a long time, and which is so much the more necessary at present in that old wood is becoming rare, and that it is necessary to use green.



STOVES FOR DRYING WOOD.

The processes of drying that are known up to the present are numerous, and are nearly all of them based upon smoking, the object of this being to exhaust the sap and to substitute therefor empyreumatic vapors having creosote for base, and which, on combining with the pyroligneous acid of the wood, deposit in its cells a preservative principle that protects it against dry rot and the attack of insects.

There are cases, it is true, in which smoking cannot be practiced; for example, with wood designed for the manufacture of furniture, by reason of the persistence of the empyreumatic odor, and with wood that must not show any artificial coloration.

The apparatus shown in the annexed engraving is designed for the drying of wood either by smoking or by the use of hot air, and consequently gives just such products as may be desired. The fire-place, A, which is situated at a slight depth beneath the surface, is so arranged that the fuel may be burned slowly or produce a hot fire, according as smoke or hot gases are to be obtained. The products of combustion, after crossing the fire-bridge, are distributed through the chamber, B, whence, through lateral apertures, C, in front and behind, they pass to the upper chamber, D, situated immediately beneath the drying-room floor, which is formed of longitudinal brick arches, F, that support double T-irons.

Each of these arches has openings, O, O, ***, in the key that may be opened or closed by means of registers, G, G,***, maneuvered from outside.

Over and between each of the arches run collecting flues, V, V,***, that contain apertures, U, U,***, in their upper part, and between which pass transversely the beams, H, that support the wood to be dried or the track upon which runs the truck that carries the charge. The orifices, U, U,***, all communicate with the flue that runs to the chimney, T, through a passage provided with a register.

The ceiling of the drying-room, E, is formed of longitudinal, very light, superposed arches supported by I-irons, and so arranged as to form two distinct compartments which do not communicate with each other, but which are connected with the drying-room through orifices provided with valves that are maneuvered from the exterior. The drying-room likewise communicates with the exterior through its roof, by means of small and uniformly distributed chimneys, each provided with a sand cover.

The sides of the drying-room are formed of three thin walls (as shown in the figure), which are cross-braced by longitudinal courses of bricks. The whole is connected by iron cross-braces provided with keys. Each of the walls therefore contains two flues of wide and distinct circulation. The inner one, Q, communicates with the lower compartment of the drying-room ceiling, and the external one with the upper. Each room is provided with a wide, hinged, folding door containing apertures for the insertion of a thermometer and for removing a trial specimen of wood from time to time, in order to see how the operation is advancing.

The lower chamber, D, which communicates with the stove, E, through the apertures, O, O,***, is capable of communicating likewise with the lateral flues, Q, Q,***, this being effected by the simple maneuver of registers, F, F, ***, at the bottom of each of the flues.

The stove under consideration is capable of effecting all the operations of drying, and the arrangements are such that two of them can be placed alongside of one another, or four grouped together around one central chimney, and the drying be done with hot air or with smoke, and through ascending or descending currents, at will.

The entire arrows indicate a drying effected through a descending current. After passing into the chambers, B and D, in succession, the products of combustion flow through the apertures that are opened and closed by the registers, F, into the interior flues, Q. They pass along these to the lower division of the ceiling, whence they enter the drying-room, E, and descend to the orifices, U, U,***, of the flues, V, V, which lead them to the chimney.

On the contrary, if the registers, F, are closed, and the valves, G, open, the current ascends, and the gases, after traversing the stove from bottom to top, and entering the lower compartment, redescend through the flues, Q, Q, and go to the chimney. This is the mode preferred.

The drying of green planks is effected in less than four days with one of these drying-rooms.—*Chronique Industrielle.*

MANAGEMENT OF MEASLES, WHOOPING-COUGH, AND DIPHTHERIA.

By GEORGE B. FOWLER, M.D., Visiting Physician, New York Infant Asylum.

NEW YORK, Oct. 11, 1884.

A. N. BELL, M.D., Chairman of Committee, etc:

I cheerfully comply with your request for my view of the value of the hygienic measures instituted by you at the country home of the New York Infant Asylum, for the suppression of a most severe epidemic of whooping-cough, measles, and diphtheria, during the summer and autumn of 1883.

The home is situated in the town of Eastchester, Westchester County, N. Y., upon an elevated and attractive plot. It consists of a large main building and five outlying cottages, besides an old residence. With the exception of this last, each house was constructed under careful supervision to meet the wants and emergencies natural to an institution devoted to the care of women and children.

Early in July, when the number of inmates was about 320 (223 children and 97 women), whooping-cough began to prevail, and soon after a case of measles appeared in a ward of the main building. Without going

into details (which I have done in another place), suffice it to say that, despite the efforts of resident officers and visiting physicians, the disease spread from child to child, and very soon an epidemic was prevalent. In harmony with the generally recognized fact that the acute infectious diseases of children are very closely associated and liable to follow each other, we, in a very short time, discovered several cases of diphtheria.

When it is remembered that, as a general rule, those children attacked by one disease were either suffering from another, or just convalescing, and taking into consideration the peculiar malignant type of measles which prevailed, and the universal prevalence of several pulmonary, brain, and bowel complications, some conception may be formed of the conditions with which we had to cope.

On account of the triple character of the epidemic and the fact that in frequent instances a child would be suffering from two or even *three* diseases, the difficulties in the way of successful isolation were very great; for there were twelve classes of children to be kept separate:

1, measles; 2, measles with whooping-cough; 3, whooping-cough; 4, convalescent measles; 5, doubtful whooping-cough; 6, doubtful measles; 7, those who had been exposed to measles; 8, those exposed to whooping-cough; 9, diphtheria; 10, doubtful diphtheria; 11, whooping-cough with diphtheria; and 12, healthy children.

However accurately the division might have been made at any one time, it is evident that the prevalence of either of the prevailing affections in an isolated colony hitherto free from it would instantly upset the entire arrangement, and necessitate another decision. And thus it frequently happened to us. To have successfully carried out quarantine and isolation, a more expensive provision and a greater number of assistants than were at our command, or that of any other institution, would have been necessary. Under your orders and immediate supervision, very energetic measures were instituted looking toward thorough disinfection and as complete isolation as possible under the circumstances.

I have no doubt but that, had your specific directions been followed from the first, the epidemic would have been of shorter duration and milder type. But on account of an unfortunate misunderstanding and conflict of authority, the separate wards were subjected to the fumes of a small quantity of sulphur, which proved ineffective. When your orders were strictly carried out, the entire house or cottage being vacated by the inmates, the bedding, clothing, and utensils only remaining, the fireplaces, windows, and outside doors closed and sealed, and the communicating doors left open, and several hundreds of pounds of sulphur burned, disinfection was accomplished.* This process was repeated successively several times, from house to house, with a continued round of vacating and reoccupancy, and the diseases immediately ceased to prevail, and have not since appeared. During the height of the epidemic we had, at your suggestion, recourse to tents in which to place our diphtheria cases and their isolated nurses.

In my opinion, properly constructed tents, such as were used on this occasion, offer the best possible means of treating infectious diseases, in that the ventilation is perfect and constant, and, under proper care, draughts are impossible. The manifest improvement in our cases thus housed or tented maintained this well-established fact.

And, in conclusion, let me add that I am convinced that the practice which you have instituted at the institution, of a systematic and thorough fumigation with sulphur of every cottage once every four weeks, as a measure of purification and protection, has mainly contributed to the health of the inmates during the past year.

COMPLETION OF WASHINGTON'S MONUMENT.

THE obelisk erected in the city of Washington to the memory of the Father of his Country is at last completed, and was dedicated with appropriate ceremonies on Saturday, Feb. 21, 1885, as the national holiday of Washington's birthday, Feb. 22, fell this year on Sunday.

The ceremonies began by an assemblage of people at the base of the monument, an address by Senator Sherman giving a history of the structure, which was begun in 1848. Music and religious services followed. Then came Masonic ceremonies. The functionaries declared that the square, the level, and the plumb had been applied to the obelisk, and that its corners were found to be square, its courses level, its walls skillfully erected according to the plan. Grand Master Myron M. Parker scattered corn and poured out wine and oil, emblems of nourishment, refreshment, and joy, and brought into use certain historic relics with which General Washington was intimately connected. The gavel was prepared for and used by General Washington as Grand Master *pro tem.* in laying the corner-stone of the National Capitol on September 18, 1793. The sacred volume belonging to Fredericksburg Lodge, No. 4, of Virginia, upon which Washington took his first vows of Masonry; that belonging to St. John's Lodge, upon which on April 30, 1789, he took the oath of office as the first President of the United States; the "Great Light" belonging to the Alexandria-Washington Lodge, No. 22, of Alexandria, Va., upon which he, as Worshipful Master, received the vows of initiates; the apron worn by him, which was worked by Madame Lafayette; a golden urn containing a lock of his hair, belonging to the Grand Lodge of Massachusetts; the "Lesser Light," one of the three sperm candles borne in Washington's funeral procession, were exhibited. The address of the Grand Master concluded as follows:

"Know ye, all ye people, that we be Free-Masons, loyal and true citizens, obedient to law and order, and can never be concerned in plots and conspiracies against true government. The immortal Washington, himself a Free-Mason, devoted his hand, his heart, his sacred honor, and if need be, his life also, to the cause of freedom of conscience, of speech, and of action, and from his successful leading has arisen this nation. To him and the memory of his deeds a grateful people have erected this memorial in the capital which he founded, and which will bear his name to remotest ages, a monument towering above other monuments as he towered above other men."

Colonel Thomas L. Casey made the presentation speech to the President of the United States.

The President, Chester A. Arthur, then responded as follows:

"FELLOW COUNTRYMEN: Before the dawn of the century whose eventful years will soon have faded into the past—when death had but lately robbed this Republic of its most beloved and illustrious citizen—the Congress of the United States pledged the faith of the nation that in this city, bearing his honored name, and then, as now, the seat of the General Government, a monument should be erected 'to commemorate the great events of this military and political life.' The stately column that stretches heavenward from the plain whereon we stand bears witness to all who behold it, that the covenant which our fathers made, their children have fulfilled. In the completion of this great work of patriotic endeavor there is abundant cause for national rejoicing, for while this structure shall endure, it shall be to all mankind a steadfast token of the affectionate and reverent regard in which this people continue to hold the memory of Washington. Well may he ever keep the foremost place in the hearts of his countrymen.

The faith that never faltered, the wisdom that was broader and deeper than any learning taught in schools, the courage that shrank from no peril and dismayed by no defeat, the loyalty that kept all selfish purpose subordinate to the demands of patriotism and honor, the sagacity that displayed itself in camp and cabinet alike, and above all that harmonious union of moral and intellectual qualities which has never found its parallel among men—these are the attributes of character which the intelligent thought of this century ascribe to the grandest figure of the last.

But other and more eloquent lips than mine will today rehearse to you the story of his noble life and its glorious achievements. To myself has been assigned a simple and more formal duty, in fulfillment of which I do now, as President of the United States, and in behalf of the people, receive this monument from the hands of its builder, and declare it dedicated from this time forth to the immortal name and memory of George Washington."

A grand procession then took place through Pennsylvania Avenue to the Capitol, where, in the Chamber of the House of Representatives, a great audience of distinguished personages assembled, and were addressed by several eloquent speakers.

The history and general nature of the structure will be gathered from the engraving, and the following report, recently made by Col. Thos. Lincoln Casey, engineer of the Washington monument, to Gen. Newton, concerning operations upon the Washington monument for the year 1884.

During the past year and working season the masonry of the shaft and pyramidion have been substantially completed. The topmost stone was put in position December 6, 1884.

At the close of the working season of 1883 the shaft had been carried to the height of 410 feet above the floor. During the past season the remainder of the shaft, and the entire pyramidion, 55 feet in height, have been finished, adding 145 feet to the structure.

Owing to the thinness of the walls of the shaft in their upper portions, additional care was taken in the construction of those parts, and between the levels 440 and 452 galvanized iron clamps were freely used. From the level 452 to 500 the walls are entirely of marble, of through and through blocks, and from the level 470, where the ribs of the pyramidion begin, the several courses are secured to each other by mortises and tenons cut in the builds and beds of the several stones.

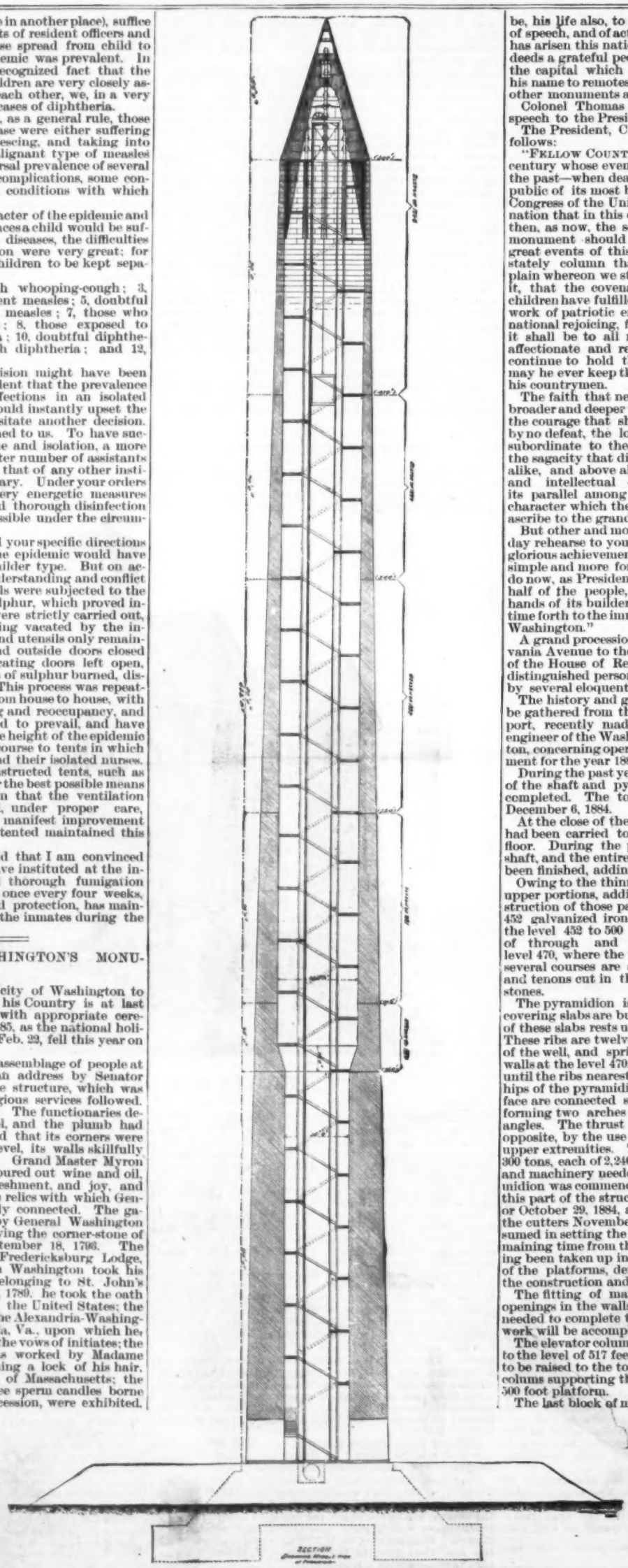
The pyramidion is built entirely of marble, and its covering slabs are but seven inches in thickness. Each of these slabs rests upon projections on the marble ribs. These ribs are twelve in number, three upon each side of the well, and spring from the interior face of the walls at the level 470. They are then carried upward, until the ribs nearest the angles of the shaft meet in the hips of the pyramidion, while those in the center of each face are connected still higher up by voussoir stones, forming two arches intersecting each other at right angles. The thrust of a corner rib is transmitted to its opposite, by the use of horizontal stones between their upper extremities. The weight of the pyramidion is 300 tons, each of 2,240 pounds. Work upon the materials and machinery needed in the construction of the pyramidion was commenced in June, 1884, the last stone for this part of the structure was delivered by the contractor October 29, 1884, and the last stone was dressed by the cutters November 21, 1884. Thirty days were consumed in setting the marble of the pyramidion, the remaining time from the commencement of the work having been taken up in the construction and assembling of the platforms, derricks, and machinery required in the construction and in dressing the marble.

The fitting of marble slabs as shutters to the nine openings in the walls of the pyramidion is all that is needed to complete this part of the structure, and this work will be accomplished in a few weeks.

The elevator columns of the iron framework were built to the level of 517 feet, permitting the elevator platform to be raised to the top of the shaft, while the four outer colums supporting the landings were terminated in the 500 foot platform.

The last block of marble for the shaft was delivered by the contractor, Mr. Hugh Sisson, of Baltimore, June 23, 1884, and was set in its place August 9, 1884, thus completing the shaft to the height of 500 feet in four working seasons.

Mr. Sisson finished the delivery of marble under his contract in a most satisfactory manner, November 21, 1884, at which date it was closed. Twelve hundred and eighty-eight blocks of marble, containing 26,900 cubic feet, and 294 blocks of granite, containing 5,500 cubic feet, were



THE WASHINGTON MONUMENT.

*The amount of sulphur used was three pounds to every thousand cubic feet of space to be disinfected.—A. N. B.

built into the shaft during the season. The pyramidion is composed of 262 separate pieces of marble, containing 3,764 cubic feet of dressed stock.

Since the completion of the new foundation, June 7, 1880, 34,604 tons have been added to the weight of the structure and the settlement due to this weight has been as follows: Southwest corner, 2·02 inches; southeast corner, 2·02 inches; northeast corner, 2·03 inches; northwest corner, 2·08 inches.

It will be observed that the difference between the least and greatest settlements under this load is less than $\frac{1}{8}$ of an inch.

An appropriation of $75,000 is asked for the ensuing year, to go on with the completion of the monument and its surroundings in all their details.

The construction of the Washington monument was begun in the early summer of 1848, by the Washington National Monument Society.

The structure, as designed by Robert Mills, was an obelisk 600 feet in height, with a very flat apex, surrounded at the base by a pantheon, with a peristyle of marble columns 100 feet high.

Shortly after the commencement of the work, the height of the obelisk was reduced to 500 feet, and the building of the pantheon deferred to some future date. The foundation of the obelisk as constructed was 80 feet square at the bed of foundation, and this bed was placed 7 feet 8 inches below the general level of the ground about the structure. The foundation was 28 feet 4 inches thick, and was 58 feet 6 inches square at its top. It was built of large pieces of bluestone gneiss, put in the masonry as they came from the quarry, the interstices between the masses being filled with spawls and a mortar composed largely of fat lime and sand.

The shaft was commenced 55 feet $1\frac{1}{2}$ inches square at the base, with walls 15 feet thick.

These walls had a facing of large grained white marble, in blocks of 2 feet rise and from 18 inches to 15 inches thickness, sawed without reference to the quarry bed, and rubbed smooth, and a backing of blue gneiss-stone rubble.

The walls as constructed contemplated a finished height of 600 feet for the shaft.

By the year 1854 the obelisk had been built to the height of 152 feet, and by 1856 some 4 feet more were added, making the total height of the marble shaft 156 feet $4\frac{1}{8}$ inches.

At its top the sides averaged 48 feet $9\frac{5}{8}$ inches in length. The well in the interior was 25 feet 1 inch square. The axis of the shaft leaned $1\frac{3}{4}$ inches to the northward. The thickness of the walls at the top was 11 feet $10\frac{1}{16}$ inches.

The weight of this obelisk and its foundation was some 31,152 tons, and the cost of the structure $300,000.

On the 19th of January, 1877, the Washington National Monument Society conveyed by deed all their property, easements rights, and privileges in the monument to the United States, but no further work was done toward continuing the obelisk until 1878, when, under the act of August 2, 1876, providing for the completion of the Washington monument, and the joint resolution of June 14, 1878, to enable the joint commission to carry this act into effect, work was commenced upon the strengthening of the foundation, to the end that the obelisk might be completed to the height of 525 feet. By the 28th of January, 1879, a sufficient quantity of materials, with the necessary tools and machinery, were collected to commence work. This work consisted in enlarging the area of the foundation by digging away 70 per centum of the earth under the old foundation, and to a depth of 13 feet 6 inches beneath it, and replacing this earth with a mass of concrete extending 18 feet within the outer edges of the old foundation, and 23 feet 3 inches without the same line, thus giving a new foundation 126 feet 6 inches square, and enlarging the area of the foundation from 6,400 square feet to 16,000 square feet. To distribute the pressure of the shaft over this new foundation, the old rubble stone base was torn from under the walls of the shaft, and replaced by a concrete underpinning extending out on to the new concrete slab. In this work 51 per cent. of the cubical contents of the old stone foundation was removed, and 48 per cent. of the area of the shaft undermined.

The work of strengthening the foundation was completed the 29th of May, 1880, and as finished the new foundation is 36 feet 10 inches in depth, and extends down to a level 6 inches below the permanent level of water in the site upon which the work is situated. The work of building the obelisk was commenced August 7, 1880, the old shaft having first been reduced to a height of 150 feet, and, as before stated, the masonry of the obelisk was completed December 6, 1884.

As finished, the monument is 555 feet $5\frac{1}{8}$ inches in height, the shaft being 500 feet $5\frac{1}{8}$ inches high, and the pyramidion or apex 55 feet. The topmost point is 597 feet 3 inches above mean low water in the Potomac and 596 feet 9·36 ± inches above the mean level of the Atlantic at Sandy Hook, N. Y., as determined December 1, 1884, by the U. S. Coast and Geodetic Survey. The shaft as completed is 55 feet $1\frac{1}{2}$ inches square at the base, and 34 feet $5\frac{1}{8}$ inches square at the top, where the walls have a thickness of 1 foot 6 inches. The batter of the sides is 0·247 ± of an inch to 1 foot in rise.

The height of this shaft is slightly greater than nine times the width of the base. Its width at top is five-eighths the width of the base, and it would come to a point at a height of $2\frac{5}{8}$ its present height.

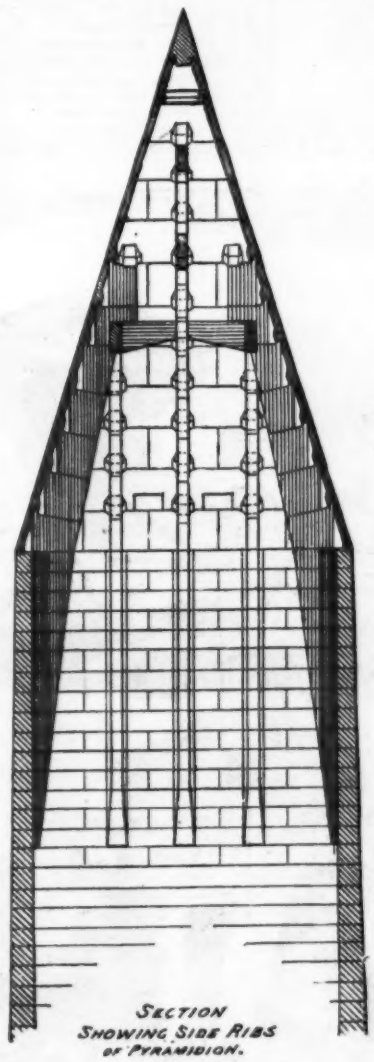
The walls of the new portion are faced with a fine-grained white marble from the Beaver Dam quarry in Baltimore County, Maryland, and backed with granite from several of the New England quarries. The courses are uniformly 2 feet in rise, the blocks of a wider bed than their rise, and the bond, the Flemish, alternate header and stretcher. The marble is very strong, fine-grained, and durable, and weighs 178$\frac{1}{2}$ pounds to the cubic foot. The walls at the level of 160 feet were reduced in thickness to 8 feet 7 inches, but from that level are carried up plumb on the inside, giving a well of 31 feet $5\frac{1}{2}$ inches square.

An iron frame, supporting a staircase and elevator machinery, is carried from the floor to the top of the shaft. The weight of the structure is as follows:

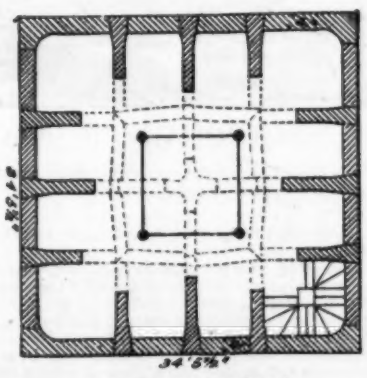
	Tons.
Weight of foundation and earth upon it	36,912
Weight of 150 feet of old portion of shaft	22,373
Weight of new portion of shaft	21,260
Weight of pyramidion	300
Weight of iron frame	275
Total weight	81,120

It is quite certain the pressure upon the bed of foundation nowhere exceeds 9 tons per square foot, and is less than 3 tons per square foot near the outer edges of the foundation. The smallest factor of safety against cross-breaking in the foundation is 3·65 ±. No further material load should ever be put upon the existing foundation. During the progress of the work of introducing the new foundation, the several corners of the shaft settled as follows: Southwest, 2 ± inches; southeast, 2·34 ± inches; northeast, 2·23 ± inches; northwest, 1·90 ± inches. The total settlement of each corner since work was commenced and to the present date is, for the southwest, 4·02 ± inches; southeast, 4·36 ± inches; northeast, 4·26 ± inches; northwest, 3·98 ± inches. The greatest difference, nearly a half inch, between the southeast and northwest corners, occurred during the introduction of the new foundation, and aided materially in correcting the deviation of the shaft from a perpendicular.

The lightning conductors consist of a metal tip upon the apex, connected by a copper rod, with four other



SECTION SHOWING SIDE RIBS OF PYRAMIDION.



PLAN AT REF. 500'

THE WASHINGTON MONUMENT.

copper rods passing to the upper extremities of the four wrought iron columns supporting the elevator machinery. The bottoms of these columns are connected by copper rods with the water in the well in the center of the foundation.

The cost of the work to the present date is as follows:

Expended by the United States	$887,710.31
Expended by Washington Monument Society, about	300,000.00
Total	$1,187,710.31

So much of this most difficult work having been accomplished, I wish to bear witness to the skill, zeal, and ability of my assistants, Capt. George W. Davis and Mr. B. R. Green, in the execution of such parts of the work as were particularly intrusted to them, and to the efficiency of the master mechanic, Mr. P. H. McLaughlin, in carrying out the orders given him.

Quite an amount of work is required to finish this structure and its surroundings.

1. The interior stairways and platforms, although provided with iron frames, are now covered with their temporary wooden coverings. The quantity of wood now inside the monument is some 2,816 cubic feet, a sufficient amount of inflammable matter to ruin the structure, should it, by any chance, take fire. The treads of the stairs (no risers need be put on them) and the platform coverings should be of iron or steel, made as thin and light in weight as is consistent with strength and durability. Metal hand rails and elevator fronts must also be provided for the stairs and landings.

2. In order to light the shaft and the passages leading to it, a dynamo of about 2,000 candle power must be set up in the engine house, and incandescent lights supplied to the several platforms.

3. The engine house at the monument must be enlarged some 6$\frac{1}{2}$ feet to the south, to accommodate the dynamo machine and its engine, and a low galvanized iron double roof, with louvered and glass sides, must be erected over the engines. The entrance to the engine house, and from it to the floor of the shaft, should be through a covered passage beneath the terrace, similar to the one in the east side, which is to be exclusively for visitors to the structure.

4. The presentation blocks on hand number one hundred and one. Of this number it is probable some are not suitable for introduction in the walls. Those that are to be secured in the walls will have to be reduced to tablets from 4 to 8 inches in thickness. A depression may then be cut in the face of the wall, and the tablet inserted and fastened by bronze expansion bolts to the backing. The attention of the commission is especially invited to this subject, to the end that the selection of the stones to be inserted may be made at an early day.

5. The backing of the first 150 feet of the walls is of rubble masonry, so roughly constructed along many of the joints as to catch the water of condensation running down the face of the well, and to deflect it into the interior of the walls. This portion of the interior face should be plastered with Portland cement mortar, rubbed down hard, and lined off as coursed ashlar.

6. The present floor of the monument is some 5 inches below the finished floor of the structure. This space was left for a granite curb and cast iron covering plates, over the drum and shaft pits, and the foundation of a tiled floor. This work should be done as soon as the stairs, presentation blocks, and plastering are finished.

7. The two doorways leading into the monument should be closed by building them up with thin marble walls, the stone to match with the bond and material of the facing. Entrances to the floor of the shaft should then be made through short passages beneath the terrace, and a flight of steps running up under the closures of the doorways. This closing of the doors will present the structure to the eye and mind as an obelisk pure and simple, and will undoubtedly add to the dignity and impressiveness of the structure.

8. Two methods of treating the terrace at the foot of the shaft have been suggested. One method proposes to erect a retaining wall of the most rare and beautiful marbles around the terrace, which wall is to be surmounted with a marble balustrade and ornamented with bronzes and mosaics. At the center of each face is to be a set of broad, double stairs, extending from the general level of the site to the esplanade, which is to be paved in marble tiles of approved patterns, the whole work to be designed in all its details by the first artists and architects. The other method of finish proposed is to fill earth about the present terrace and joining with it, and to extend this filling so far from the monument as to fade the slopes of the embankment gradually into the surrounding surfaces, and this to be done with so much skill as to give to the mound an appearance as far from artificial as possible. This mound is then to be planted with trees and shrubs, paths are to be laid out, a pavement to be put around the foot of the monument, and far enough from it to prevent the storm-waters from washing out the filling; and a keeper's lodge is also to be built near the work to accommodate the watchmen and visitors. The amount of filling required for this work is about 275,000 cubic yards.

9. The elevator machinery is now arranged for a speed of 50 feet per minute, and a load of ten tons. As there is no counterpoise to the car, it is recommended to retain the present speed and simply to convert the platform into a passenger car by the addition of proper seats, linings, and cabinet-work.

10. The boiler-house and smoke-stack of the boiler for the elevator and dynamo engines should be located in the western part of the monument lot, and the steam to the engines and the exhaust steam from them should be led from and to the boiler by pipes laid in an underground passage. A new boiler-house, stack, and 80 horse-power boiler are needed.

11. It has been observed during the construction of this work that when any motion took place in the structure, due to addition of weight, the two north corners of the monument were the first to settle. This is believed to be due to the falling away of the earth on the north side of the structure, thus reducing the conjugate pressures on that side, and to the proximity of the pond just north of the terrace, in the south margin of which are numerous springs. In the interest of increased stability of the monument, and for the better arrangement of the terrace slopes and grades, it is recommended that the pond just north of the obelisk be filled to the level of its banks, requiring for this purpose about 83,000 cubic yards of earth.

The estimate for the above work is as follows:

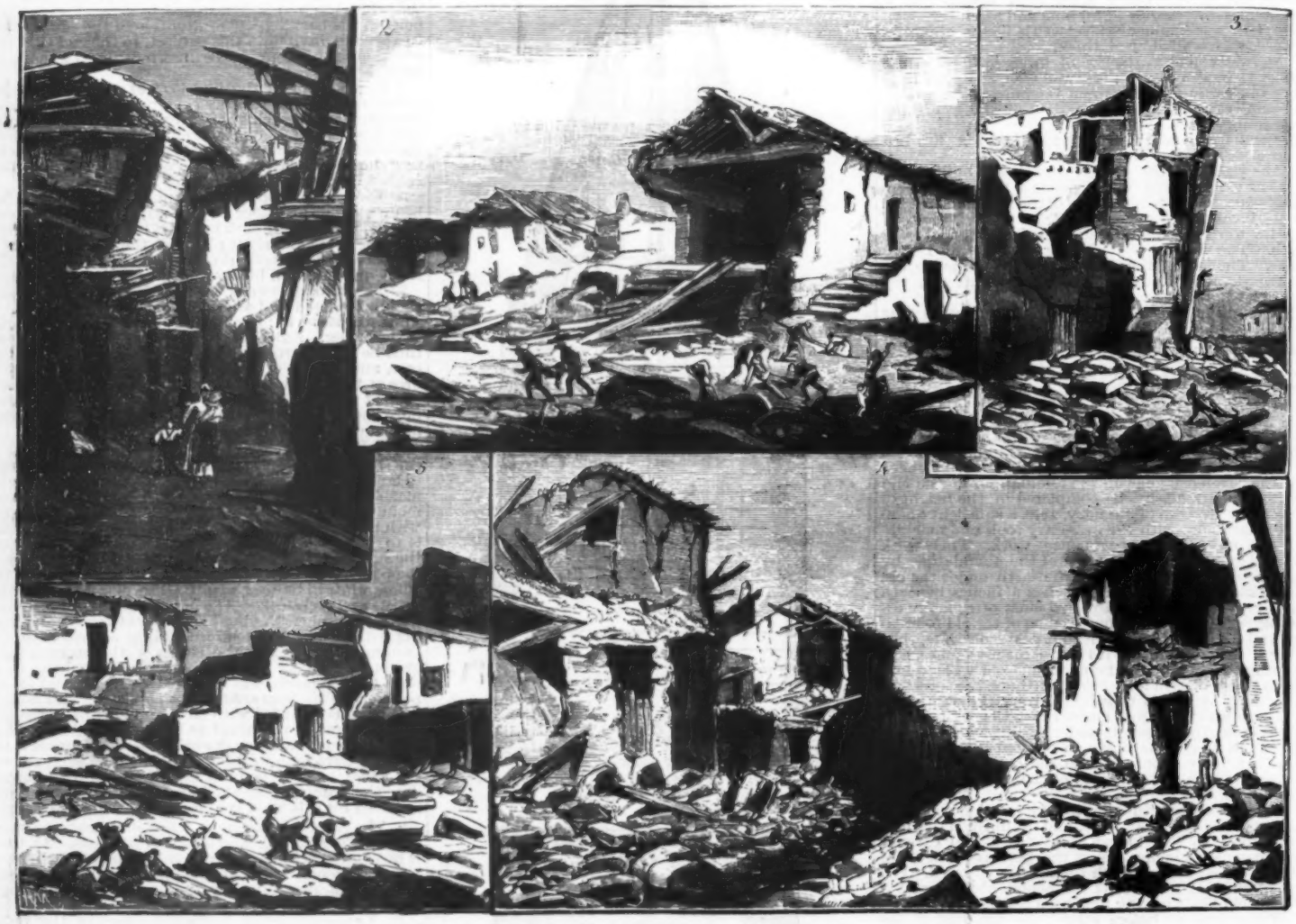
1.	Iron work of stairs and platforms and elevator fronts	$25,000
2.	Electrical lighting apparatus	3,300
3.	Engine-house and approaches	4,000
4.	Insertion of presentation blocks	6,000
5.	Cementing interior walls	2,000
6.	Paving floor and covering drum pits	2,000
7.	Closures of doorways and passages	5,000
8.	Completion of terrace: By marble wall	538,000
	Completion of terrace: By earth filling and grading	89,500
9.	Change in elevator car	2,000
10.	Boiler-house and boiler	10,000
11.	Filling pond	25,000
	Estimate with earth terrace	$166,800
	Estimate with marble wall	612,300

THE GREAT EARTHQUAKE IN SPAIN.

Of the tremendous havoc caused by the earthquake on Christmas eve, Dec. 25, 1884, in the town of Alhama, and the disturbance and distress it occasioned in the cities of Malaga and Granada, we present a sketch by Mr. Dietrichsen, a German artist, of the ruins of Albunuelas; this is a smaller town, but has suffered almost as severely as Alhama, and more than any other place in the province. Four hundred and fifty-seven houses were destroyed at Albunuelas; a hundred and seventy-three persons were killed, among them the parish priest and many of the principal inhabitants; and two hundred and sixty-six were wounded. Many of these remained for hours buried among the ruins before assistance could be obtained to dig them out. The road to Albunuelas passes through a wild country full of spots celebrated in the history of Spain as being the scene of conflicts with the Moors. Among them are the heights from which Boabdil looked his last upon Granada.

The town of Periana, at the foot of the Sierra Nevada mountains, but in the province of Malaga, was almost totally destroyed, the number of houses thrown down being seven hundred and fifty, while about a hundred persons were killed, and two hundred injured. The church, the town hall, and the convents were all destroyed. Only fifty houses are left standing, and they are in a ruinous state. At Velez Malaga, fifty-three persons were killed and seventy injured; four hundred and fifty houses, a convent, and two churches are in a ruinous state. This was a town of 26,000 inhabitants, near the seacoast, five miles east of the city of Malaga. At Canillas two hundred and eighty houses were totally destroyed, and two hundred and twenty are in a ruinous condition.

The King of Spain, Alfonso XII., lately returned to Madrid, after a tour in which he visited most of the places which have suffered by the earthquake. His Majesty refused to accept any banquets or other public entertainments during the course of his tour, and requested that funds destined for such purposes should be given to the national subscription for the relief of the sufferers. He took much trouble, personally, in the distribution of the money which he had brought with him for the purpose among the families most in need of assistance, the wants of the widows and orphans being in the first place inquired into and relieved. The King went about among the sufferers and spoke to them with great kindness, and was visibly moved at the spectacle of such wide and deep distress. He was everywhere welcomed by the people with touching demonstrations of gratitude, as well as of loyalty. We give sketches from the *Illustrated London News* and *La Ilustracion Espanola*.



THE EARTHQUAKE IN SPAIN.

1, 2. Ruins in Albunuelas.—3, 5. Two houses in Alhama, from which twenty-three persons were rescued.—4. Enciso Street, Alhama, as it appeared twelve days after the earthquake.

The largest room in the world, under one roof and unbroken by pillars, is at St. Petersburg. It is 620 feet long by 150 in breadth. By daylight it is used for military displays, and a battalion can completely manœuver in it. Twenty thousand wax tapers are required to light it. The roof of this structure is a single arch of iron, and it exhibits remarkable engineering skill in the architect.

THE BUDDHIST THEORY OF EVOLUTION.

The theory of evolution held by adepts in Buddhism is the outcome of the researches of an immense succession of investigators, believed to be qualified for their task by the possession of spiritual faculties and perceptions of a higher order than those belonging to ordinary humanity. In the course of ages the block of knowledge thus accumulated concerning the origin of the world and of man and the ultimate destinies of our race, checked and examined at every point, verified in all directions, and constantly under examination throughout, has come to be looked on as the absolute truth concerning the evolution, past and to come, of man and the planets he is destined to inhabit. The initiated members, or "adepts," of the Buddhist cult claim to have attained, through intense self-absorption, a knowledge of physical laws of nature not yet understood by western science, investing them with extraordinary powers known as spiritualistic, such as clairvoyance and the disintegration and reconstruction of matter by a simple effort of will. They claim in fact to be in possession of potential faculties which will only be generally developed in future stages of evolution. This religion, which is wholly unaggressive and seeks no converts, attracts many on account of its claims to be in accord with all established scientific fact, and by its incorporation of so patent a truth as the doctrine of evolution as an integral part of its system.

A brief examination of these claims, and a glance at the past and future of man's evolution as thus elaborated, can hardly fail to be of interest, if it fails to carry conviction.

It is impossible, and unnecessary, to attempt to follow briefly the mystic subtleties of belief that have fascinated the Oriental mind, and been to it for ages what the pursuit of practical science has been to western nations.

Shortly stated, the Buddhist divides the human entity into seven principles, the higher of which have not yet reached their full development. The first three are of the earth, and done with at death. These are (1) the body; (2) vitality, or the life principle, an indestructible force which attaches itself to other objects after the decomposition of the body; (3) the astral body, "an ethereal duplicate of the physical body," which can under certain circumstances become disembodied and visible as a ghost; (4) the animal soul, or seat of all animal desires; (5) the human soul. The other two can be passed over, as they are still in embryo, and belong to a wholly superior and future condition of existence. The fifth, and, later on, the sixth principles make up a man's continuous individuality through successive incarnations.

The solar system consists of seven planetary chains. The one with which man is concerned consists of seven planets, through each of which he has to pass seven times in order to accomplish his evolution. These are the earth, Mars, which is in a state of entire obscuration or rest as regards the human life wave, Mercury, just beginning to prepare for its next human period, and four other planets, which are composed of an order of matter too ethereal for telescopes to take cognizance of. The system of worlds is compared to a system of towers standing on a plain, each of many stories, man's progress being a spiral round and round the series, passing through each tower as it again comes round to it, at a higher spiritual level than before. The impulse to the new evolution of higher forms is given by rushes, not a continual flow, of spiritual monads coming round the cycle in a state fit for the inhabitation of new forms, and those which for millenniums have gone on merely repeating themselves, then start afresh into growth, and rise rapidly, through intermediate, to the higher forms. The spiral character of the progress, and the fact that the tide of life passes from planet to planet in gushes, accounts for the gaps in the various kingdoms of nature. Each time a spiritual monad arrives on a planet, it has a complicated process of evolution to perform. It is many times incarnated before it passes onward, and man has many incarnations in each great race, the normal sum being not far short of 800, with an interval of at least 1,500 years between each, spent in the "world of effects, or heaven of ordinary theology." In the first planetary round, man inhabited an immense but loosely organized body, and could not be called intellectual. In the second he becomes a firmer body, while in the third he is rather in form of a giant ape than true man, yet of concrete body and advanced intelligence. In the fourth, the present round, his intellect becomes fully developed, and he achieves enormous progress.

We now approach the transcendental mystery of mysteries, our future development. The fifth round will be occupied with a struggle between physical intellect and spirituality. In the sixth round a state of perfection of body and soul will be attained which can hardly even be imagined; while as to the seventh round the occult teachers themselves are solemnly silent—it being altogether too God-like for realization. At the end of each planetary round an intercyclic period of extraordinary exaltation must be undergone. It is by processes of occult training that adepts project themselves precociously into the fifth round, or possess themselves of the attributes of fifth round men, so as to be able to explore the mysteries of nature and of other states of existence, and to assimilate knowledge by clairvoyance independently of observation.

We now exist in the fifth race of the fourth round. The first and second races developed no civilization, but the third and fourth did do so several millions of years ago, though no traces of such now exist. The periods of the great root races are divided by vast convulsions or geological changes, which cut them off at the appointed time, leaving only a few survivors behind, who rapidly relapse into barbarism. The fourth race lived on "Atlantis," and reached its apogee in the Eocene age, when this great continent showed the first symptoms of sinking, a process that occupied it down to 11,446 years ago, when its last island, Poseidonis, went down with a crash. "Lemuria" was drowned with its high civilization and gods about 700,000 years earlier than Atlantis, or just before the early part of the Eocene age, the relics of its third race inhabitants existing in some of the flat headed aborigines of Australia. The true Chinaman is interesting

as a relic of the fourth race. The civilizations of the ante-glacial period were superior to those of Greece and Rome, or the Egyptian, which was in its decadence 12,000 years ago. The uninhabited Arctic regions will prove not only to have enjoyed a tropical climate, but were likewise the seat of one of the most ancient civilizations of the fourth race. Atlantis belonged to the Miocene times, and the cataclysm which destroyed it came at the appointed time, "otherwise it would be impossible for the best seer to calculate the exact hour and year when such cataclysms great and small have to occur." The relics of these former civilizations are hidden in strata which have never been geologically explored, deep in the unfathomed ocean beds.

An important part of the Buddhist creed is the belief in the alternation of periods of repose with periods of activity. As man sleeps every twenty-four hours, and vegetation subsides and revives with the seasons, so rest periods follow each incarnation. The tide wave of humanity flows on to each of the seven planets seven times, and passes through its seven races and ebbs away again, but the great rest period of our planetary chain does not begin until the seventh round of humanity is perfected. At an incalculably remote period the whole of the seven planetary chains of our solar system will pass into a period of rest, and finally the whole universe itself will have its great cosmic night. After the long night of a planetary chain, the animal and vegetable world resume their arrested activity, but when the time arrives for all the planetary chains of our system to pass into their night, each planet, as the seventh round man quits it, is annihilated instead of merely becoming invisible, and there is an outflow from every kingdom of its entities. These will rest in lethargic sleep in space until brought into life again at the next solar period, and will then form the soul of the future globe. We have every indication that at this very moment such a solar night is taking place, while there are two minor ones ending somewhere.

At the beginning of the next solar day period the hitherto subjective elements of the material worlds, now scattered in cosmic dust, will form into primordial ripples of life, and, separating into differentiating centers of activity, combine in a graduated scale of seven stages of evolution.

Every orb will pass through seven stages of density, until its solidification and desiccation at last reach a point when it becomes a relaxed conglomerate, and its constituent masses cease to obey the laws of cohesion which hold them together.

Evolution takes its rise in the atomic polarity which motion engenders. In cosmogony the active and passive forces correspond to the male and female principles. The attribute of the universal spiritual principle is to expand and shed, of the material principle to gather and fecundate. These become consciousness and life when brought together. Our planet, like an iceberg, is merely a state of being for a given time, and its present appearance, geological and anthropological, is but transitory and will pass away.

Such are the beliefs and doctrines concerning evolution* held by the Oriental scholar, who holds in pity the benighted ignorance of Western so-called science. The book from which they are gathered is sober earnest, and I am asked whether the Buddhist ideas on evolution are in accord with the discoveries of science. The mere statement of the belief, shorn of its mysticism, is a sufficient answer. The importance attached to the numeral 7 seems puerile, and its reason is not easy to discover; it is claimed that the colors of the spectrum and the notes of the musical scale are seven, and that there are seven kingdoms in nature. There is one seeming scientific fact, however, which, though it has escaped the "adepts," favors so far the belief in evolution by gushes, and is still unexplained. The first appearance of many forms of life on our planet, it is well known, is very sudden. All the groups of mollusca, and especially in the case of ammonites, appear at once fully developed and in great variety of species, and never develop into anything higher. So with the echinodermata, the crustacea, insecta, the different orders of fishes, many orders of reptiles, marsupials, ferns, and dicotyledons. All these seem to have been evolutionized in a very sudden manner, and as yet afford no grounds for controverting the Buddhist belief that they are well developed arrivals from other planets.

J. STARKIE GARDNER.

* Condensed from Mr. A. P. Sinnett's book, "Esoteric Buddhism" (Trubner & Co.), and as far as possible in his own words.

CARE OF STREET CAR HORSES.

THE following is the report of Committee on Stables and Care of Horses made to the members of the Third Annual Convention of the American Street Railway Association:

The importance of information upon this subject is shown by the fact that nearly two-fifths of the investment in street-railways is in buildings and horses; and of the expense of operating, upward of 35 per cent. is consumed in the maintenance of stables and horses.

The care which the horse receives at the hands of the managers of street railways has much to do with the economy of operating; for it is evident that well-arranged stables, careful attendants and skillful drivers, with wholesome and sufficient feed, go a great way toward prolonging the life and usefulness of the horse in street-car service.

The subject of stables naturally claims attention first, and in this connection it must be understood that at least eighteen and, perhaps, twenty hours out of every twenty-four, the horses in this service are confined within the stables year in and year out. Thus three-fourths of the life of the horse is spent in the stable. Considering that plenty of light and pure air are essential to the healthy condition of the horse, to furnish this should be the first object in building a stable.

In selecting material, such should be chosen as will be least likely to absorb and retain the impurities which will always be found within such buildings. Great care should be taken to have the drainage perfect, and if underground to have the drains so inclined, trapped, and tight in the joints as to quickly and completely take away whatever is deposited in them. Arrangements should be provided to flush them often with water, and if possible to have all traps and catch-basins well ventilated, so as to carry outside of the stable any foul gases which may accumulate there The theory of surface drainage for stables has many supporters, and deserves careful consideration from those about to build. If surface drains are frequently flushed or washed, this manner of draining would seem to call for no objection. The matter of drainage being settled, the next question is light and ventilation.

Arrangements should be made to admit air in sufficient quantity without creating a draught.

Roof ventilation is desirable, but not sufficient, as the air of a stable containing many horses is heavy, and will not rise without a current of air from near the floor to assist. Light can be admitted from high openings in the sides of the building, but these should not be depended upon for side ventilation, as the height renders them insufficient to move the air, and the location, usually over the heads of the horses, causes them to be dangerous as means of a draught.

Doors on opposite sides of the stable connected by a passageway running behind the horses, this passageway having ventilation from the roof, is a desirable means of ventilating a stable, as in case the wind blows too strongly in one direction the doors on that side of the building can be closed, while air is admitted from the opposite side.

As a matter of convenience, it may be desirable to have all stalls upon the ground floor, but such an arrangement is not practical in large cities, on account of the high cost of land, and horses may be as well established on the second or third floor, provided these floors are constructed properly as regards the drainage, and provided with "runs" leading to the outside in two or more directions to be used as escapes in case of fire.

The stalls should be constructed with a view to give the horse as much freedom as possible consistent with economy in utilizing the space. Experience demonstrates that the width should not be less than four feet in the clear, or the depth less than nine feet. The height of the partition between the horses should be at least four feet, and at the heads carried three or four feet higher, in such a form as to admit light and air without allowing the horses to bite and otherwise annoy each other. Single stalls are preferable, although double stalls, with swing-bars between the horses, are in favor with many good stable experts. The floor of the stall should pitch toward the gutter about one and a half inches to the nine feet. A good construction for stall floors is to lay the surface for about four feet inward from the gutter with close-grained hard wood, like maple, in strips of four or five inches wide and two inches thick, leaving a space between, three-quarters of an inch wide, to allow the urine to pass off without being absorbed in the bedding.

The best form of manger, or feed-box, is of cast iron, formed so as to have no square corners for feed to accumulate, and of sufficient depth to prevent the horse from "nosing" his feed out. No rack is needed for loose hay; this can be fed in small quantities from the floor. A passageway, say four feet wide, between the heads, or in front of the stalls, for the purpose of feeding is desirable; this should be ventilated by windows or doors at each end and a flue leading to the roof above. The loft for feed should have a tight floor, so that the steam and ammonia from the stable underneath will not contaminate the provender stored therein. It should be constructed with windows to admit light and air from the sides, and with roof ventilation at the top. Suitable receptacles should be provided for the manure *outside* the stable, and all refuse and manure should be removed frequently, and before it has had time to heat and steam.

The custom of building stables with cellars to receive the manure is not recommended; and unless there is yard-room enough to pile the manure compactly outside the building, it should be removed from the premises daily. The space allowed for rear floorway between the stalls should be sufficient to permit the removal of horses from one row without interfering with those on the other; for this purpose, ten feet is a fair allowance.

The plan of arranging stalls in sections, so as to have the horses allotted to the care of one man stand together, is a good one; also that of having a separate drinking trough for his horses. If a common drinking

THE EARTHQUAKE IN SPAIN.—RUINS OF ALBUNUELAS.

trough is used, it should be centrally located and supplied with running water.

Twelve feet in the clear is recommended as a good height for each story, although some advise more, and some are content with even less.

Arrangements outside the building to dry and air the bedding are very desirable when straw or hay is used, and if shavings or saw-dust, bins for storage should be provided. If any substance except wood is used for floors, bricks are recommended, as they are easily renewed when worn and less liable to cause the horses to slip than stone, asphalt, or cement.

In coming to the subject of the "care of horses," it is suggested that the first care should be exercised in the selection of horses to be purchased. The theory that any kind of a horse that can be had for from $100 to $150 will do for street-railway use is a bad one.

The buyer of street-railway horses has a somewhat difficult problem to meet from the fact that the horse most desirable to him usually commands a higher price than he, *i. e.*, the corporation, however, he represents, is willing to pay. A good buyer will always insist upon the necessary qualities in the horse he buys, without too much regard to price. In the first place, only sound horses should be bought. Although horses unsound in some respects *may* be used to some advantage, it is never best to buy them in that condition, as every railroad manager knows that the exacting labor they are subject to will cause unsoundness in some form or another soon enough. A good disposition and easy gait should be considered as absolutely necessary. The head and general appearance of the countenance will show the disposition, and a trot of fifty feet will show the gait. Color should have nothing to do in the selection except to cheapen the price, as is the case with white, gray, buckskin, and bald-faced horses. The feet and muscles of the legs should be carefully looked at, as these are the mainstay of a railroad horse.

A flat-footed horse should never be accepted.

The age should never be less than five or over nine years, as a general rule; a horse of twelve years of age, however, if sound, may be accepted at a considerable reduction in price.

After the horse is selected and placed in the stable, the first thing to do is to accustom him to the feed, and break him to the labor. We would never think of putting on a conductor or driver without first instructing him in the duty expected of him, and place him under the direction of an old hand for practice. This rule should be followed with the horse. The first day he should be allowed to rest. After that, if he takes his feed well, he may be put to half-work with a careful driver, and should be worked no more than this for the first six or eight weeks, at least. All green horses should be given in charge of the best drivers, who will take pains to break them in to the work.

The care of the horse in the stable includes feeding and grooming. Upon the question of feed, perhaps, the first cost or what is termed "economy" has considerable to do.

It is generally admitted that cut hay and corn meal is the cheapest, at first cost, of any feed in use; but experience has shown that this feed is too hearty and fattening, and that horses fed upon it for several years without change become more subject to eruptive diseases and also to colic, inflammation of the stomach, and indigestion. It is calculated that at least five cents per day can be saved in this feed on each horse, over the cost of feeding oats and long hay, and that the extra loss on horses fed with meal only will not amount to the sum saved at the end of the five or six years' service of a railway horse. To the credit of railway managers it is found that this conclusion is not accepted generally; and that while some are found to strictly adhere to what is termed the natural feed of the horse—oats and long hay—very many compromise the question by giving one such feed daily, or, at least, lighten up the corn meal by mixing bran or wheat middlings, in proportion of about half and half by measure. The mixing or preparing of the feed should be intrusted to as *few* persons as possible; but the practice of each hostler dealing out the feed to the horses allotted to him is not objectionable, although many stable experts prefer to confine the hostler's duty simply to watering and grooming the horse and the care of his stall, and to provide one man to distribute the feed to each 100 or 125 horses. In general terms, it should be the care of the stable-master to make the horses under his charge as comfortable as possible, while keeping them in condition to do the work required of them. They should be watered frequently and fed regularly, not less than three feeds a day, and thoroughly groomed not less than twice a day. In warm weather, they should be carefully cooled off after coming in from work, and in cold weather well blanketed. Disinfectants should be freely used; common lime, either dry or in the form of whitewash, is recommended as effective and inexpensive.

As shoeing is a matter of considerable importance to railway managers, it is proper that all intrusted with the care of street railway horses should inform themselves as to the best form of shoe, and the best manner of setting it. There is but little difference of opinion among the well-informed upon this subject as to the desirability of a light shoe over a heavy one, and that for horses traveling over a paved street, a shoe made of soft iron is preferable to one made of steel, on account of its being less liable to slip. In all cases the shoe should be fitted to the foot, and not the foot to the shoe. On the question of hot or cold fitting, W. H. H. Murray may be quoted. He says: "The weight of authority is nearly the same in either scale. The advocates of cold-fitting declare that they can fit a shoe with rasp and file as evenly as the necessities of the case require, and that this can be done at no great cost of time or skill. They, moreover, charge that both reason and analogy are in opposition to burning a horny surface, and declare that it honeycombs the wall of the foot, and prevents its natural and healthy growth.

"The disciples of hot-fitting, on the other hand, declare that few men can level the foot, or so hammer and file the shoe, that the fit shall be what is required, and that only by burning can the connection between steel and horn be made sufficiently close and solid."

It must be admitted that good arguments can be used on both sides of this question, but in the end both sides bring up with this fact, that whether by hot or cold fitting the shoe must be fitted evenly and solidly to the foot. As a matter of interest in this connection, an estimate made by a French professor concerning the muscular fatigue resulting from the use of heavy shoes may be quoted:

"If, at the termination of a day's work, we calculate the weight represented by the mass of heavy shoes that a horse is condemned to carry at each step, we arrive at a formidable array of figures, and in this way are able to estimate the amount of force uselessly expended by the animal in raising the shoes that surcharge his feet. The calculation I have made possesses an eloquence that dispenses with very long commentaries.

"Suppose the weight of a shoe is 1,000 grammes (about 2¼ lb. avoirdupois). It is not excessive to admit that a horse trots at the rate of one step every second, or sixty steps a minute. In a minute, then, the limb of a horse whose foot carries one kilogramme (2¼ lb.) makes an effort necessary to raise kilogramme after kilogramme, a weight of sixty kilogrammes (132 lb.). For the four limbs, this weight in a minute is represented by 60×4=240 kilogrammes (528 lb.). For the four feet during the hour, the weight is 14,000 kilogrammes (30,800 lb.), and for four hours, the mean duration of a day's work in these omnibuses, the total amount of weight raised has reached the respectable figure of 57,000 kilogrammes (125,400 lb.).

"But the movement communicated to these 57,000 kilogrammes respresents an expenditure of power employed by the motor without any useful result, and as the motor is a living one, this expense of strength represents an exhaustion or, if you like it better, a degree of fatigue proportioned to the effort necessary for its manifestations. This calculation is most simple and readily understood. It is to be noted, nevertheless, that I have omitted a considerable factor, which is, that the weights I have tabulated are situated at the extremities of the limbs, and that the arms of the levers on which the muscles act to raise them being infinitely shorter than those of the physiological resistance to which these weights are added, the intensity of their action ought, therefore, to be singularly increased.

"But to measure this intensity of action would require a mathematical aptitude which I do not possess. I will not, therefore, dwell upon this point, notwithstanding its importance, and am content to signalize it. Otherwise the figures speak for themselves, and tell us that the diminution in the weight of horse-shoes is not an unnecessary consideration, so far as the useful application of the horse's strength goes."

After a careful consideration of the above calculation, must not all admit that the lightest possible shoe consistent with the service should be used upon street-railway horses?

The question of calking the shoe must be settled by the condition of the street over which the animal travels. Many believe that a calk is not necessary on paved streets, except in the winter season, when ice and snow are liable to interfere; and that if a calk is used at all it should be a low one, so as to raise the frog but slightly from contact with the street, and that care should be taken to have all calks of an even height, to allow the horse to set his foot squarely and evenly upon the ground.

Upon the question of nailing the shoe, a quotation from Fleming seems to "hit the nail on the head": "The shoe ought to be attached by nails to those parts of the wall where the horn is strongest and toughest. In the fore-foot, these parts are in front and along the sides to the quarters. There the horn becomes narrow and thin, and the nails find less support, and are nearer to the living textures. This is more particularly the case toward the heels, especially the inner one.

"In the hind-foot the wall is generally strong toward the quarters and heel. These facts at once give us an indication as to the best position for the nail holes. In the fore-foot, nails may be driven through the wall around the toe, as far as the inside quarter and a little nearer the heel on the outside. In the hind-foot they may be driven around the toe and even up to the heels with impunity."

Nails should be turned out as quickly as possible, as the higher they go the less thickness of hoof is found, and extreme care should be used not to prick or press the sensitive part of the foot. Too many horses are made almost worthless from the effect of "blind stabs," which means driving the nail into the quick and then withdrawing it, and driving it again so close to the wound as to irritate it and cause it to suppurate within the foot and work out at the top. Such cases are the result of careless nailing, and frequently terminate in what is called "foot-rot." The difficulty in tracing the exact cause of such trouble arises from the fact that the horse does not show lameness for one or two days.

As the feet of horses working only on paved streets and standing continuously upon wooden floors are liable to become hard and dry for lack of sufficient moisture, it is necessary that the stable-master should adopt some measure of supplying this need. A simple way, and one that can be followed in any stable, is to furnish each hostler with a pail and sponge, and require him to wet the fore-feet of all his horses once or twice a day. The water should be applied particularly to the part where the hair and horn meet, and to the heel and frog. A good idea is to dissolve about a half pint of clean salt in each pailful of water used. This plan should be continued daily, and not occasionally. The stable-master should inspect his horses daily, as to their fitness for work, and "lay off" and nurse any that do not "take their feed," or show lameness.

The next care that the horse requires at the hands of railway managers is that of furnishing suitable *drivers*. The best stabling, grooming, feeding, and shoeing cannot counteract the effects of bad driving. Those men whose duty it is to select and educate the drivers on street cars should be most faithful and efficient, and no man should be retained as a driver who has not the necessary patience and judgment. Many horses become vicious and balky by ignorant and careless driving, and a quick-tempered driver is liable to be a costly one.

The last care that comes to us in the treatment of the street-car horses is to select or sort out and dispose of those that have become unfit for the service.

This demands good judgment, for the difference between the price obtained for a worn-out horse and a new one to take the place is considerable, yet it is folly, and worse than bad judgment, to retain and feed horses unable to work, for it does not take them long to "eat their heads off," as the saying goes. All horses should be disposed of as soon as it appears that their capacity for full railroad service is gone.

BUILDING BY COMPRESSED AIR.

According to the *Annales des Ponts et Chaussees*, compressed air has been very successfully used in laying the foundation masonry of the movable dams of Coudray and D'Evry, in France. The plan adopted was somewhat similar to that employed in constructing the Antwerp Docks, the caisson being built of plate iron, and suspended by screws from a timber frame resting upon piles. The caisson was 20 m. (65·6 ft.) long, by 7·8 m. (25·5 ft.) wide, and 6·08 m. (22·9 ft.) high; the working chamber was 8¼ ft. high in the clear. In form it was rectangular, with vertical sides, formed of T iron and plate; the roof was made by fourteen transverse plate girders, each 3 ft. deep, with an iron skin above and below, and the intervening space filled with sand; the further counter-weighting was obtained by using pigs of iron. There were three air-locks, of ordinary construction, the central one large enough to pass stone, etc., 4 ft. by 2 ft. by 1½ ft. into the working chamber. The weight of the caisson, not including the air-locks, was 1,804,000 lb., and including all appliances 2,640,000 lb.

When first used, the air escaped at the numerous joints in the ironwork of caisson; but though this was overcome at first by an application of clay, Serbat cement was finally applied.

In connection with this article is a reference to the friction on the sides of the caisson in sinking, as determined in practice by M. Montaguier; the gentleman quoted found that in sinking a distance of 10 ft. into fine sand the frictional resistance was 103 kilogrammes per square meter of surface exposed to the sand (21·0 lb. per square foot), and in gravel it was 208 kilogrammes (42·4 lb. per square foot). This was connected with the use of compressed air, and the consequent presence of a film of escaping air between the sides of the caisson and the material penetrated.

In the case of the Coudray barrage, 20 screws with a total power of 300 tons were used in lifting the caissons as the masonry was built, and this operation was assisted by a number of 15 ton screw jacks acting between the masonry and the roof of the working chamber. In this barrage the distance from base of masonry of the surface of water was about 18½ ft.

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